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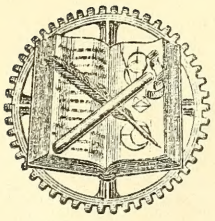
ENGINEERING MAGAZINE.

VOLUME IV.

JANUARY–JUNE,

1871.



NEW YORK:
D. VAN NOSTRAND, PUBLISHER
23 Murray Street and 27 Warren Street (up stairs).

1871.

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E. E. Williams

VAN NOSTRAND'S
ECLECTIC
ENGINEERING MAGAZINE.

NO. XXV.—JANUARY, 1871.—VOL. IV.

BIOGRAPHICAL SKETCH OF JESSE L. WILLIAMS, CIVIL ENGINEER.

From Stuart's "Civil and Military Engineers of America," now in press.

The professional life of the subject of this sketch has extended through a period of more than 40 years, and been connected with the rise and progress of the public works of Ohio and Indiana, and with other great enterprises which have effected important changes in the condition of the country west of the Alleghany mountains.

The aggregate length of the various lines of public works, coming under his supervision as engineer, during their location and construction, cannot, it is believed, be less than 2,500 miles. The total amount of expenditure upon these works, while under his charge, probably exceeds $20,000,000. Commencing his professional life at a time when the superior facilities afforded for the carrying on of inland trade and commerce by means of canals, were attracting attention everywhere to their construction, he will, probably, close it, as this kind of improvement is becoming secondary in importance to another of still higher perfection, the railway. Indeed, it may be said that in the regions west of the Alleghanies, he has witnessed the origin, the growth, the maturity and the decline of the canal system.

Mr. Williams was born in the State of North Carolina, in May, 1807. His parents were members of the Society of Friends, and about the year 1814, emigrated to Cincinnati, Ohio. The vicissitudes attending almost every business enterprise, at the close of the war of 1812, involved his father in pecuniary losses and prevented him from giving his son a liberal education. Although he has often been heard to regret the want of opportunities and leisure in early life for the acquisition of higher attainments in learning, yet, as tested by the demands of a long, varied and successful professional career, it would seem that his early disadvantages have been mainly overcome. His acquirements, theoretical and practical, under the guidance of a sound discriminating judgment, have been adequate to the faithful discharge of the numerous difficult and complex duties of the varied official stations in which he has been placed. He commenced his career as rodman in the corps of engineers on the Miami and Erie canal in the State of Ohio, in 1824, and subsequently had charge as assistant engineer of the heavy and difficult division next to Cincinnati during its location and construction.

In the spring of 1828, the Chief Engineer of the State of Ohio, David S. Bates, appointed Mr. Williams to locate the canal from Newark to Chillicothe, including the Columbus side-cut. After this duty was performed, the construction

of the divisions of this work between Circleville and Chillicothe was committed to his charge.

The sound judgment and the steady perseverance which marked the course of Mr. Williams in the discharge of the various difficult duties of his profession attracted public attention, and early in 1832 he was invited by the Board of Commissioners of the Wabash and Erie Canal, to take charge as Chief Engineer of the location and construction of that important work, which was then about to be commenced under the authority and control of the State of Indiana.

In 1834, Mr. Williams was appointed with William Gooding, as associate engineer, to survey the White Water Valley for the purpose of determining the practicability of constructing a canal through that valley to the Ohio river.

On the passage of the law authorizing a general system of internal improvements approved January 27th, 1836, Mr. Williams was appointed Chief Engineer of all the canals of the State, including the Wabash and Erie Canal, which, by the provisions of the new law, was extended from its original terminus at the mouth of the Tippecanoe river, to Terra Haute.

At this period of time, Mr. Williams had under his charge about 800 miles of canals, portions of which were in progress of location and construction. In September, 1837, the Chief Engineer of Railroads and Turnpikes having resigned, these works, also under like progress, were, by action of the State Board of Internal Improvements, placed under the charge of Mr. Williams. As State Engineer, his supervision then embraced more than 1300 *miles of public works.* Afterwards, when the appointing power was changed, he was elected by the Legislature to the same position, and continued therein until the office was abolished at the session of 1841; when the prosecution of the public works was entirely suspended.

Perplexing duties, and great labor and responsibilities, were necessarily attached to the position which was so long occupied by Mr. Williams, as the State Engineer of Indiana. The general direction of every survey and location, the plans of every important structure, and the letting of all contracts, came, in their order, under his immediate supervision. In the course of the summer and autumn of 1838 no less than 13 public lettings took place, by order of the Board of Internal Improvements, in different parts of Indiana, at intervals of about two weeks. With such facilities for travelling as belonged to that period, a punctual attendance at the numerous lettings and the making of necessary preparations for them, must have taxed the mental and physical energies of one man in no common measure. It was computed at the time by those who felt some interest in such matters, that the journeyings of the State Engineer, performed mainly on horseback, during the three months amounted to at least 3,000 miles. After transacting business at one place until the close of the day, the duties of his station often required his presence early next morning at another place a day's journey distant, and it has been stated that Mr. Williams on several occasions made such journeys on horseback, and through sparsely settled districts of country, between the setting and the rising of the sun. This fact illustrates, in some measure, the nature of a few of the difficulties that were encountered and overcome by the pioneer engineers in the earlier improvements of the Western States.

After the 1st of March, 1846, Mr. Williams, in addition to his duties and responsibilities as State Engineer, became, by appointment of the Legislature, ex-officio a member of the Board of Internal Improvements and Acting Commissioner of the Wabash and Erie Canal. In the discharge of the various duties of these stations, he continued to act for a period of about 2 years, having charge also of the selections, management, and sales of the canal lands. As State Engineer, the public works in every part of the State were under his charge from 1836 to 1842, and his special supervision of the Wabash and Erie Canal was continued during this period.

In 1837, Mr. Williams was appointed Chief Engineer of the Madison and Indianapolis Railroad, which position he held until 1842. The prostration of State credit that followed the financial revulsion of this year, checked the progress of public works in the United States. From 1842 to 1847, Mr. Williams was occupied in mercantile and manufacturing pursuits at Fort Wayne, the place of his residence.

Before leaving the capital of the Sta e of Indiana, he was offered the Presidency of the Madison and Indianapolis Railroad, then about to be completed under the management of a company, the office of President and Chief Engineer being united in one. In June, 1847, Mr. Williams was appointed Chief Engineer of the Wabash and Erie Canal, resuming at that date charge of this work after 5 years retirement. He continued to occupy this position up to 1859, thus making his professional services, in connection with this important work, extend over a period of more than 22 years.

In February, 1854, Mr. Williams was appointed Chief Engineer of the Fort Wayne & Chicago Railroad, which position he held (in addition to his charge of the Wabash and Erie Canal) up to the time of the consolidation with the Pittsburgh Railroad, in 1856, and for a few months afterwards, until the work could be opened to Plymouth, and a temporary connection formed with Chicago, by the way of the Michigan Southern & Northern Indiana Railroad. Since that time, excepting as a Director of the consolidated company, he has had no official connection with this work. In its first conception as a great through line to the Northwest, and in giving form and vitality to the first movements in its favor in Indiana, he bore an active and efficient part, and to this extent his friends may justly claim for him an important share in its paternity. Others carried out the idea, and to them is due the credit of accomplishing the great work, which, in connection with the Pennsylvania Central Railroad, forms one of the chief routes between Chicago and the cities on the Atlantic seaboard.

In July, 1864, Mr. Williams was appointed by President Lincoln a Director of the Union Pacific Railroad, on the part of the Government. The term being but one year under the law, he was reappointed each succeeding year until the work was completed in 1869, receiving commissions from three successive Presidents.

In the Fall of 1864, he accompanied the consulting engineer of the Company, Colonel Silas Seymour, over the first 40 miles of the route, then in progress of construction to a point on the Platte River west of Fremont. The policy adopted by the Board of making very elaborate preliminary surveys, so necessary to the selections of the very best route for this national work, was earnestly seconded by Mr. Williams, as may be seen in his able reports to the Secretary of the Interior. In July, 1867, Mr. Williams made a tour of inspection over the road to the end of the track. On the 13th of June, 1868, Mr. Williams was instructed by the Secretary of the Interior, to "examine and report specifically, as to the condition of the Union Pacific Railroad, where it has beeen constructed or surveyed." From his report to the Hon. Secretary, dated August 15th, 1868, it will be seen that this important duty was ably performed. The President of the Company accompanied him in a special train to the end of the track, then 660 miles from the Missouri River, stopping to examine every station and all important structures. At the end of the track a company of United States cavalry for protection against Indian hostilities, with twenty Government wagons for transportation, were in readiness, and the whole party, under command of General Dodge, Chief Engineer of the Company, passed thence on horseback over the entire line of surveys to Salt Lake, about four hundred miles.

The Secretary in his annual report to the President of the United States in 1868, referring to this specific examination of the Union Pacific Railroad says, "Mr. Williams is an experienced civil engineer, and performed the duty committed to him in a very satisfactory manner."

On the 19th of January, 1869, Mr. Williams was appointed Receiver of the Grand Rapids and Indiana Railroad, by the United States Court of the Western District of Michigan. This work, 320 miles long, is designed to connect the City of Fort Wayne with Little Traverse Bay and the Straits of Mackinaw. The Court, for the protection and benefit of all interests involved, ordered the Receiver to borrow money and build the road as required by law. In addition to the duties and responsibilities ordinarily belonging to a financial trust like this, Mr. Williams also took upon himself a professional charge as Chief Engineer of the work. These several duties, especially the financial, were found so exacting as to leave no time for the proper per-

ormance of Pacific Railroad duties. He herefore, in October, 1869, resigned the position as Government Director of the Union Pacific Railroad, and retired with the well merited esteem of the Government for valuable services rendered.

TECHNICAL EDUCATION—THE RENSSELAER POLYTECHNIC INSTITUTE.*

The subject of scientific education never before challenged public attention as it does now. The deep interest felt in this question among our English friends, is exhibited by the space devoted to its discussion in the columns of our contemporaries across the ocean.

We can not perform our duty in the matter in a better way than to lay before our readers a large portion of the late report of a committee appointed to inquire "whether any change in the course of study of the Rensselaer Polytechnic Institute is desirable."

This institution has for many years held the foremost place among the technical schools of this country, and counts among its graduates many of our most prominent engineers.

The committee consisted of Messrs. E. Thompson Gale, Alexander L. Holley and Clarence E. Dutton. No selection could have been better; gentlemen of such varied culture, familiar with the past history of the institution, were certainly better fitted for the important task set before the committee than would have been either professional instructors or merely practical, although successful, engineers.

In the preface to the report the committee offer the following explanation :—

This report is not put forward as a complete plan for engineering instruction, or for the organization of an engineering school, but rather as preliminary to such a plan; and the committee are aware that some of their recommendations may seem revolutionary. They believe, however, that the course suggested is at least in the direction of *closing the breach between Theory and Practice*, which is universally admitted to be the weak point in all our systems of technical education. And if the experts who read this report will take the time to correct what they consider fallacious or impracticable, and to add the weight of their endorsement and the benefit of their amendments to what they consider generally good and feasible, the cause of technical education at large cannot fail to be advanced.

The following is their report :

At the commencement of their investigations the committee found themselves without definite instructions as to the range which their inquiries should cover, or the limits within which their recommendations should be confined. They therefore took the liberty of deciding these points for themselves, feeling that they had no peculiar prejudices or prepossessions to gratify, and no foregone conclusions to urge; and whatever may seem new, or revolutionary, or experimental, in their recommendations, has been developed entirely by a careful consideration of the facts brought to light by earnest study of the problems before them. They have neither courted nor shunned conclusions, but have merely followed whithersoever the facts seemed to lead. Whatever views may be taken respecting any or all the matters herein submitted, it is felt that they ought, at least, to be credited to a deep and earnest desire to benefit the Institute.

The committee seem to have been appointed in response to a conviction, widely spread among the graduates of the institution, that the courses of study pursued, embraced too large a proportion of purely theoretical instruction, and too small a proportion of technical, or practical instruction. How far such a conviction may have prevailed, your committee cannot say. But it seems quite certain that it existed among some whose opinions are entitled to great respect, and it furthermore seemed that a still larger number were convinced that the question of the relative proportions of these studies was an open one, and needed very careful in-

* From the report of a Committee of the Trustees of the Rensselaer Polytechnic Institute, concerning the System of Instruction.

vestigation. Believing that this was the question which was chiefly to engage their attention, the committee endeavored to obtain the advice of a large number of American engineers, mechanics and educators, whose high intelligence and extended reputations would give great importance to their expressions. With this view, a circular letter, accompanied by a copy of our present curriculum, was addressed to more than 60 gentlemen, known to us as possessing eminent qualifications, both by education and great practical experience in its application, to assist the committee in drawing its conclusions. The form of the letter was as follows :

"DEAR SIR :—The Trustees and Faculty of the Rensselaer Polytechnic Institute, desiring to obtain such information as will enable them to determine what course of study is best adapted to secure the aims and purposes of the institution in their charge, respectfully solicit from you an expression of opinion upon the following questions :

"1*st*. Does the course of study announced in the Catalogue (a copy of which is also sent you) embrace too great a proportion of the higher mathematics, and too small a proportion of the natural and physical sciences ; or could the former be curtailed and the latter increased with advantage ?

"2*d*. Does the course of study seem to you to embrace too large a proportion of purely theoretical instruction, and too small a proportion of practical instruction ?

"3*d*. Considering the qualifications demanded of American Civil and Mechanical Engineers, is there any study omitted in the course which ought to be introduced ; it being premised that such an addition involves a corresponding reduction in some other study already prescribed ?

"4*th*. Do you think it would be feasible to impart elementary instruction in practical and mechanical engineering, by means of lectures, given by experts, in machine shops and on the ground where construction is going on ; the object being, not only to better fit men for practice, but to illustrate and vitalize theoretical study ; or would such instruction be too superficial to warrant the necessary expenditure of time ?"

(Signed by the Committee.)

It will be sufficient here, to state generally that the hopes and expectations of the committee were not fully realized in the results of their correspondence ; and their disappointment may be readily explained. The questions propounded were difficult enough to solve, with all the facilities of a full knowledge of the structure and organization of the Institute, derivable from proximity to it, and from frequent intercourse with the faculty. How much more so, then, to those who possessed no such facilities ? The committee were not slow in discovering that they were merely shifting their own responsibilities upon the shoulders of those whose means of carrying them were inferior to their own. Still, the keen perception of many of these gentlemen, and their practical experience in the same difficulties, enabled them to divine, approximately, the status of the questions, and to give such conclusions as their valuable experience had formed in their own minds. Hence, although the results of the correspondence fell below expectations, it was by no means fruitless. As was to be expected, there was a wide diversity of opinion ; but the general current, with respect to the importance of matehmatical training, tended strongly in one direction, viz. : *that so far as it related to civil engineering, it should not be curtailed.* Upon this conclusion the committee have considerable to say elsewhere, and merely remark here that they accept entirely this view, so far as applicable to the civil engineering course, as being quite correct. Possibly the Board of Trustees will attach all the more weight to this conclusion, when it is stated that the committee have been converted to it from opinions inclining to the opposite direction. And this conclusion is not due merely to the testimony and authority of their correspondents, but is also strongly sustained by careful,independent investigation, and comparison of the relations of education to practice, and of the relations of this Institute to others throughout Europe and America.

But the relative proportion of mathematical training, the committee soon discovered, was by no means the whole, nor even the most considerable part of the subject-matter before them. The decision arrived at, with respect to this point, still leaves untouched the proportions of other

studies, the practical or technical, and also those having reference to the general culture of the student. The importance of these is certainly not inferior to that of mathematics. The committee assume that the objects for which the Institute exists are, not merely to provide young men with a knowledge of mathematics, and to familiarize them with with learned text-books, but to qualify them for the practical application of science to the useful arts. If this assumption is not correct, it ought to be. If it is not correct, this has no right to be called a polytechnic, or even a technic school, and if it is not a technical school, it should be made so at once. But it *does* profess to give technical instruction, and *does* contemplate the qualification of young engineers ; and the ground your committee take is, that its substance should in every possible way be fully equal to its claims. We must not be diverted from a just appreciation of the matter by the objection, which has been often raised, and will be raised again and again, that schools are designed merely to teach principles, while practice is learned only in the workshop and in the field. It is first to be settled what is principle and what is practice ; where is the boundry line that separates them ; and whether, after all, there is any boundary between them. This objection your committee have examined thoroughly, with caution and candor, and are prepared to say that there is nothing in it which needs to interfere with the execution of the duty before them, which is to establish the technical part of the curriculum on a basis equivalent to the mathematical part, and commensurate with its high importance. The drift of opinion expressed in the correspondence, is as decidedly in favor of strengthening the practical courses, as it is against weakening the mathematical courses—a view in which we equally concur, for reasons which we hope to make conspicuously evident.

At this juncture it is necessary to call the attention of the Trustees to the organization of the Institute, its system of instruction, and the subdivisions of its courses. By reference to the catalogue it will be seen that the courses are four in number, looking respectively to the education of Civil Engineers, Mechanical Engineers, Mining Engineers and students of Natural Science. Of these four, only two have a natural existence, viz. : the courses in Civil and Mining Engineering.* The course in Mechanical Engineering is not given, and that in Natural Science graduated but one student at the close of the last year. The first two years' study is common to all the sections, while during the second two years, more or less divergence and separation takes place. But the separation is for the most part imaginary, since the sections not only have many studies in common, but they recite together in all studies in which the degrees of advance are equal. This system and its advantages are so obvious as to need

*We present here an abstract of the curriculum :—Course in CIVIL ENGINEERING, four years—Division D.—*Mathematics :* Algebra, Legendre's Geometry ; *Descriptive Geometry ; Stereotomy ; English Language :* Composition and Rhetoric ; *French Language ; Geodesy :* Chain Surveying ; *Mathematics :* Geometry, Analytical Trigonometry ; *Descriptive Geometry ; Physics:* Natural Philosophy ; *English Language :* Composition and Rhetoric ; *French Language; Geodesy :* Chain Surveying, Compass Surveying.

Division C.—*Mathematics :* Higher Algebra ; *Descriptive Geometry :* General Orthographic Projections ; *Chemistry :* Inorganic Chemistry ; *Physics :* Heat ; *English Language :* Composition ; *French Language :* English Translations ; *Geodesy :* Compass Surveying, Plane Table Surveying ; *Topographical Drawing :* Elementary Drawing ; *Mathematics :* Analytical Geometry ; *Descriptive Geometry :* General Orthographic Projections ; *Natural History :* Botany ; *English Language :* English Composition ; *French Language :* English Translations, French Composition ; *Geodesy :* Adjustment and Use of Field Instruments ; *Topographical Drawing :* Maps of Farm Surveys.

Division B.—*Mathematics :* Differential Calculus; Integral Calculus, Calculus of Variations ; *Stereotomy :* Shades and Shadows, Cinematics ; *Physics :* Electricity, Magnetism ; *Chemistry :* Practical Chemistry, Blowpipe Analysis ; *Geodesy :* Levelling, Topographical Surveying, Hydrographical Surveying ; *Topographical Drawing:* Profiles, Maps of Topographical Surveys ; *Rational Mechanics :* Mechanics of Solids, Mechanics of Fluids ; *Stereotomy :* Linear Perspective, Plates, Structures ; *Physics :* Acoustics, Optics ; *Astronomy :* Descriptive and Spherical Astronomy ; *Natural History :* Geology ; *Topographical Drawing :* Colored Topography.

Division A.—*Astronomy :* Practical Astronomy ; *Physical Mechanics :* Mechanics of Solids, Mechanics of Fluids ; *Machines :* General Theory of Machines ; *Stereotomy :* Stone Cutting ; *Geodesy :* Line Surveying ; *Natural History :* Physical Geography ; *Machines :* Theory of Prime Movers ; *Constructions :* Stability of Structures, Construction of Engineering and Architectural Works. Designs for, and reviews of, Special Works ; *Geodesy :* Line Surveying, Staking out for Construction ; *Road Engineering :* Common Roads, Railroads, Canals, Tunnels ; *Chemistry :* Technical Chemistry ; *Geology :* Practical Geology, Technical Geology ; *Topographical Drawing :* Plans, Profiles, and Sections of Railroad Surveys.

Course in MINING ENGINEERING, four years—Division D.—The course identical with that in Civil Engineering.

Division C.—The course identical with that in Civil Engineering.

Division B.—*Mathematics :* Differential Calculus, Integral Calculus ; *Stereotomy :* Cinematics ; *Physics :* Electricity ; *Chemistry :* Qualitative Analysis, Stoichiometry ; *Natural History :* Mineralogy, Lithology ; *Geodesy :* Practical Trigonometry, Levelling, Topographical Surveying ; *Topographical Drawing :* Maps of Topographical Surveys ; *Rational Mechanics :* Mechanics of Solids, Mechanics of Fluids ; *Physics :* Acoustics and Optics ; *Chemistry :* Qualitative Analysis ; *Natural History :* Mineralogy, Geology, Zoology, Palæontology ; *Topographical Drawing :* Colored Topography.

Division A.—*Physical Mechanics :* Mechanics of Solids, Mechanics of Fluids ; *Machines :* General Theory of Machines ; *Chemistry :* Qualitative Analysis, Quantitative Analysis ; *Metallurgy :* General Metallurgy, Special Metallurgy ; *Natural History :* Mineralogy, Geology ; *Chemistry :* Quantitative Analysis ; *Geodesy :* Mine Surveying ; *Practical Mining :* Sinking and Driving, Exploitation, Ventilating and Lighting, Drainage, Dressing of Ores, General Management, Designs for, and Reviews of, Special Metallurgical and Mining Operations.

no discussion. It is the plan adopted at all technical schools, and no other is worth mentioning.

But to convey a clear idea of the relation of the Rensselaer Institute to the highest and best methods of technical instruction hitherto attained in this, or other countries, it appears proper to give an outline of a fair sample of the European technical school, located in a country where this form of education has been growing and perfecting for about half a century. For this purpose the school of Carlsruhe, in Baden, is selected, not because it is superior to others, but rather because it is an average specimen.

It is necessary to premise that the whole range and scope of education, from the highest to the lowest, is, in all the German States, supervised and sustained by the governments. There is no question there whether Government ought to undertake the higher education of citizens. It assumes it as a duty and a privilege; and though it requires that those who receive its benefits should pay part of its expense, it sees to it that nothing is lacking, which is in its power to provide, to the widest development, most thorough efficiency, and ample equipment of all its schools, from the highest to the lowest. Hence it has come to pass, that not only is every grade of public school the best possible in itself, but it is part of a great system. The schools are graded in such a manner, that each lower grade is preparatory to a higher, and each higher grade begins where the next lower left off. Up to a certain period and stage of development, the course of education in the public schools is uniform for all pupils. Beyond it, there is a divarication into two parts, one of which is chiefly literary, and has its culmination in the university; the other, scientific, culminating in the polytechnic school. These embranchments are coördinate, equal and complementary, each representing an education upon a basis, to a certain extext, peculiar and distinct. The preparatory school for the university is the *gymnasium*, which corresponds pretty nearly to our American college—the university itself being a type of organized education which cannot be adequately represented by anything in this country. The preparatory school for the polytechnic is the *real-school*, which has not the remotest trace of a representative among us.* In it are taught the whole range of the lower mathematics, including plane geometry, algebra, trigonometry, and conic sections; also the elements of the physical and natural sciences, with the languages, including Latin, French, and generally English, and those moral, ethical and æsthetic branches which are deemed absolutely indispensable to what is understood to be a liberal and thorough education. When the pupil of the real-school enters the polytechnic, he is reasonably proficient in every kind of general study, excepting the higher mathematics. Henceforth his efforts are occupied with higher and technical studies alone. He has mastered the elements of nearly everything which can be systematically taught, and all that remains is to give special, and in some cases, extended developments to certain branches, selected with reference to the trade or profession he expects to pursue. Among the many excellencies of this admirable, it will be seen that the polytechnic schools are not hampered with the early and preparatory education of the scholar, but have solely to deal with his professional training, a feature the importance of which cannot be exaggerated, and which relieves the schools of one of the most perplexing and annoying difficulties which your committee have been compelled to face. Returning to a synopsis of the Carlsruhe school.

This school contains the following departments:

1. The mathematical school, which is designed to comprise, in a separate course, nearly all the mathematical instruction which will be required, and thus leave the other and technical course free and unhampered. It is preparatory for three of the strictly technical courses, and the graduate in this department is still not entitled to a professionl degree. The time of study in this department is two years.

2. The school of civil engineering. In this the studies are almost purely technical and practical, with some branches of higher cultural studies. The candidate must be graduated at the mathematical school, or show that he possesses an

* This is a mistake. The Brooklyn Polytechnic Institute includes in the curriculum of its "Liberal course" all of the courses of study belonging to the real-school of Carlsruhe.—[Ed.]

equivalent amount of knowledge. The course in engineering proper is two and a half years.

3. The school of architecture. The candidate must have graduated at the mathematical school, and his technical course lasts four years in addition. This is reckoned the most difficult and most learned of all the scientific professions, and perhaps a six years' course of preparatory study in a polytechnic school may in some degree account for the precision, economy, and taste of the German architects.

4. Schools for foresters. The forests of Germany and France are under the protection of the Government, and are cultivated scientifically, and in such a manner as to yield a constant and important revenue. The officers in charge of them are usually Government officers, who are required to be men of education. Hence, nearly every polytechnic school in those countries has its department of forestry, which is taught like any other useful art. The candidate enters the school, either from the gymnasium, or the real-school, and is not required to pass through the school of mathematics. The course is three years.

5. The chemical school. This department conducts the education of certain classes of manufacturers, of chemists and druggists, and is, besides, a preparatory course for the mining schools and for metallurgy,—branches which are taught separately in great establishments like the Freyburg school of mines and the Leoben metallurgical school. The preparation required varies with the destination of the student, who must be at least seventeen years of age. The time of study is also variable.

6. Mechanical engineering. The preparation must be in the mathematical school, and the technical course is two years.

7. Commercial school. The student enters from the real-school and studies one year.

8. School for the education of employees of the post-office. The student enters from the real-school and studies two years. The course includes political arithmetic, geography, political economy, popular jurisprudence, commercial law, the mechanics of transportation, modern history, French and German literature, and the English language. Thank God there is one country in the world, where civil employees of the Government are required to know something.

9. Agricultural school. The student enters from the real-school, and studies two and a half years.

Here, then, are nine departments, or if you prefer, eight technical departments and one preparatory. Some polytechnic schools comprise more. But mining and metallurgy, even then, are taught in separate schools, located—the one near mines, the other near extensive furnace districts. All this may serve to convey some idea of the wonderful refinement of the science of education in Germany, and the exquisite adaptation of its means to ends. But how painful and humiliating the contrast, when we turn to our own country, where the field of the engineer or artisan is the widest, and where his education can be made to yield the largest results, in economy of production and rapidity of development, and yet where the advantages of education are often doubted, or even ignored.

Reverting to our own school, its disadvantages will be seen to be many. In the first place, through want of the counterpart of the real-school, it is difficult to prepare candidates for its courses of instruction, and their qualifications are therefore very low. They are not prepared with any of those elementary and fundamental sciences, which are indispensable to progress in their technical studies. They are uncultivated in everything which constitutes culture, and in short, are utterly unprepared to begin the courses they expect to pursue. There seems to be no complete remedy for this at present, and in the existing state of education we must temporize with the difficulty as best we can. There seems to be no help for it, and the Institute must continue, as heretofore, to devote the earlier year or two of its instruction to preparing its students to begin the "polytechnicum." Just now this preparation takes two years, and only two more remain to effect what European institutions require from four to six to accomplish. Although this may be amended somewhat, yet the larger part of the difficulty will remain, and must be tolerated. It is a poor consolation that no other institution in the country can do any better.

You will perceive then, gentlemen, the nature of our difficulty. You do not need to be told, in addition to this, that the Institute is poor,—almost poverty-stricken ; that the State takes no interest in us and lends us no help ; that there is no organized system of education in which our school may play a definite, adapted, coördinated part ;—all of which are difficulties to which must be superadded the difficulty arising from want of models upon which we may base our organization. Our course in this must be original, and in many respects unparalleled. We have peculiar difficulties to contend with, and we must adopt peculiar methods of conquering them, or else let them alone. We must frame a course of instruction which will cover more ground, cover a wider range between the proficiency of admission and that of graduation, and carry it out with means far inferior to those of European schools, and worst of all, do it in less time. After all, there is something amusingly national in all this. It is the way we build our railroads and bridges, create corporations, run through financial schemes, create States and Territories, build cities, bolt our dinners, and pack our pork. But let us hope the time will at last come, when, however swiftly we may organize, and however superficially or temporarily we may construct, we shall at least educate our children with deliberation, and on a sure and stable basis. Just now we are driven to expedients, and must make the best of them. It will be a miracle, though, with all this stretching and spreading out of our slender resources, if they do not lie very thin somewhere.

The foregoing comparison with the foreign technical schools serves to bring prominently into view the importance of the first recommendations which your committee desire to make, viz.: a material elevation of the standard of scholarship for admission. This, so far as it goes, will help very considerably to clear away one great difficulty, and give more time both to faculty and students. Let us remember that every day, and every text-book we can crowd back into the preparatory schools, is clear gain to us in every way; indeed the advantages are too conspicuous to need mention. The only question which can arise as to the propriety of such action is, how much can we thus crowd back, without crowding something essential out of existence altogether. We must not put into this list anything which is not usually taught in those schools where students are generally prepared for admission to college, or to this school ; otherwise we should leave a gap in the course of study, which could not be filled, except by extraordinary means. Hence we are estopped at once from raising the standard to anything like the degree to which it is eminently desirable to raise it. Still, there is room for some improvement, and possibly, by a little exertion, we may make some more.

The places where boys are prepared for college are usually high schools, and those private or endowed schools, which like the Williston, at Northampton, and the school at Andover, Mass., are established almost exclusively for this purpose. Some of these graduate scholars qualified to enter this Institution at the second year, and some even confer additional qualifications. By a little addition to this instruction, the Troy High School could enable its graduates to do the same, with a few inconsiderable exceptions. The High School contemplates the due preparation of students to enter college ; why may it not extend its preparations to admission to a higher technical school ? Indeed, this proposition merely contemplates a little hastening of a step which is sure to be taken at no very distant day in the future. The general and radical change of conviction among educators and educated men respecting the relative importance of literary and scientific cultures, educations, and professions, is even now building up everywhere in the land technical and industrial schools, and their demands for due and peculiar preparation must be met, and met by means similar to those employed to satisfy the older colleges. Nothing can be more certain than this, and why should not Troy have the honor of first recognizing the coming change, and of being the first to acknowledge and prepare for it ? Certainly the city of Troy could not do less than to respond to a request of this nature, and even might be willing to take some pains and submit to a little expense, if necessary, to render us such welcome aid.

It is recommended, then, that application be made to the Board of Education to receive candidates for admission to the

Institution, whether resident or non-resident, upon such terms as may seem proper and equitable, and permit them to receive the benefits of the High School, which may prepare them to meet the advanced requirements to be proposed by the committee; it being understood, however, that no material change be asked for in the present course of instruction at the High School. Indeed, no great change will be necessary. It is believed that by requiring High School pupils, or such of them as may contemplate entering the Institute, to complete plane geometry, elementary plane problems in descriptive geometry, lower algebra, natural philosophy, and some text-book on rhetoric, the High School course would not be seriously incommoded, and the Institute would thus be able to gain time equivalent to two-thirds or three-fourths of a year. Most of these branches are already taught, either wholly or in part, and every one of them is, in its entire extent, pre-eminently a High School study, and ought to be taught there and nowhere else. It would not be practicable, just now, to state precisely how far this arrangement could be carried by the High School, but it is suggested that the proposition be made to the Board of Education, and if accepted in a general way, the exact details could be readily arranged.

Having cleared away some of the rubbish in our path, we may now see our way more clearly to other changes. Reverting to our discussion of the courses, we may now call attention to the fact, that the civil and mining sections differ markedly in their respective degrees of excellence. It is the civil engineering course which has hitherto sustained the good repute of the Institute, and to the maintenance of its high standard of excellence, the greater share of the resources and working force of the Faculty are devoted. The mining section is most promising, and well patronized,—no less than 40 students out of the 120 of last year either receiving it or contemplating it. It was very recently organized, while the civil engineering school began with the Institute. So far as the mining section is distinct, it is sustained, just now, almost entirely by the labor of one professor. Without wishing to be invidious, and while expressing great gratification at the industry and efficiency of the faculty in general, the committee desire to commend, in high terms, the zeal, energy and enterprise displayed by Prof. Maynard under peculiarly trying circumstances. But in spite of the best that could be done, the mining course is inferior to what it ought to be, and even to what it might be. The very considerations which have led the committee to approve, for the most part, the civil engineering course, have led them to disapprove the present mining course. The objections lie chiefly in the distribution of studies. Stated in general terms, the course is too mathematical, and too little technical. The educational wants and necessities of the mining engineer are not only different from those of the civil engineer, but differ in America from corresponding wants in Europe. As the wants of the miner have everything to do with the subject, let us examine the case a little.

The difference between European and American mining is immense. Every European country has been rummaged, scoured, screened, and washed for minerals, for thousands of years. Coal lies thousands of feet below the soil; all the rich seams of metallic ores, excepting iron, were exhausted centuries ago by the wasteful, barbarous smelting of old and mediæval nations, and the poorer lodes, which would yield to more refined processes a scanty margin of profit, have been chased down into the bowels of the earth, beneath the sea, or into the cores of the mountains, where the pump can do no more, or where the volcanic heat of the earth foretells the final barrier. Thus, every century has increased, and will continue to increase, difficulties which have now become enormous, and full of imminent peril. To conquer them requires the highest resources of the engineer, the utmost intelligence of the geologist, and the best skill of the mechanic. How different in America. Our coal lies upon the surface, and the getting it is scarcely more than quarrying it. It lies in seams quadruple the thickness of those in England, cropping out on the mountain sides, where we *go up* to get it, instead of down. Our iron lies in the form of rich magnetites, and 98 per cent. hematites, in the bluffs overhanging the rivers and lakes which will float it to the blast furnace, and single seams will yield, by sur-

face, or gallery, or pit mining, hundreds of millions of tons. Our copper is dug native, within reach of the daylight; our galena has just earth enough over it to keep it from the malign influences of the air, and our silver is still extracted without the aid of prop or column. Gold, it is true, is an exception, and is now chiefly mined in shafts and subterranean galleries. You will appreciate, then, that the functions of our mining engineer are less difficult, and of a widely different nature from those of the European. His methods are less uniform, and are governed entirely by circumstances, which vary with almost every metalliferous deposit. Hence, his engineering requirements are of a lower order, less costly, with less of construction and more of mechanical appliances, less of skill and more of rude labor, and the readiest adaptation.

Another marked distinction is this. The American miner must also be a good metallurgist. In Europe it is believed that the miner has enough to do and to think of, in getting the ore, without troubling himself about what is to become of it. This accords well with the tendency to extreme division of labor prevalent in Europe. It is seldom that single establishments, like Krupp's or Schneider's, comprise consecutive processes, from the ore to the finished product. But even these somewhat exceptional establishments are so colossal in their extent, that they, too, must refine the division of labor, and establish a sort of industrial world and economy within themselves, so that the principle still holds good. In the great iron industry, the tendency has been and still is towards great variety in the products of the blast furnace, and the adaptation of special brands of pig to special purposes. Take a steam engine. Forty years ago, it might all have been built from the product of a single blast furnace. Now, it is more likely to require iron from a dozen. One brand is suitable for bed plate, another for frame, a third for cylinder and steam chest, a fourth for conversion into wrought metal for piston and connecting rods, and still other varieties for the many other kinds of stress. In short, the gist of the whole matter is, a mining engineer must know both how to get ore, and what it is good for; must be both an engineer and a metallurgist. If the vein changes its character, he must know how the change will affect the furnace and the resulting products. As a consequence, the studies he should pursue must not be merely those relating to engineering, but they must be metallurgical also. His engineering requirements will seldom be such as to demand much of the higher mathematics—with a solitary exception, to be pointed out hereafter. But he must be an expert geologist and mineralogist, and must have a substantial working knowledge of physical science, and an extensive knowledge of chemistry and assaying. His attainments may be divided into two classes:

1. Exploitation, or the practical working of mines.

2. Metallurgy, or the reduction of minerals.

The first calls for a thorough knowledge of structural geology and mineralogy, of pumping and hoisting machinery, of the steam-engine, of underground surveying, and of the mechanical appliances and methods for driving shafts, tunnels and drifts.

Metallurgy requires a knowledge of chemical analysis, assaying, mineralogy, the construction and economy of engines, furnaces, fuel, materials, and of the construction of buildings; to which may be emphatically added a knowledge of the laws and theory of heat, both as a motive force and as a reagent.

The civil engineer and architect may frequently be called upon, especially in bridge building, roof construction, arch work, water supply, etc., to apply the analytical mechanics to the problems before him, and the mechanical engineer may be similarly called upon in his profession. But it appears doubtful whether in this country, a knowledge of the higher rational and applied mechanics will ever be particularly useful to the mining engineer, in the direct line of his profession. On the other hand, his knowledge of those branches of physical and natural science, which bear directly upon it, should be as decidedly developed as the knowledge of mechanics in civil engineering. And herein seems to lie the radical difference between the two professions. The one is the application, chiefly, of mechanical science, the other of physical and natural science to the useful arts; and the stress of teaching should, so far as practicable, be regulated accordingly.

It appears to the committee that, under the present arrangement, the degree of mathematical training for mining engineers is excessive, and the training in natural and physical science, and in the technology of their profession, is deficient. It is true that the curriculum announces a reduction of the mathematics, and special extensions of the sciences and technical studies; but these modifications seem to be very inconsiderable, and very inadequate. The mining student is now required to study most of the text-books of the civil engineer, while his technical course is crowded into the odds and ends of time which are left after this exhausting course is satisfied. The changes which we recommend will be specified more fully hereafter; we confine ourselves here to saying that we recommend a much more thorough technical course, and a less stringent mathematical course, for the mining engineers.

In following out the relations of the courses of study to each other, and comparing the condition and prospects of the Institute with those of other Institutions, which are now entering the great field of technical education, your committee have had occasion to reflect frequently upon the desirableness of establishing the course of *mechanical engineering* upon a basis similar to that of civil engineering. The desirableness, indeed, no one has ever questioned, and the only obstacle is in the ways and means. So desirable does this important expansion seem, that they have been led to scrutinize very closely all the bearings of the proposition, particularly the financial bearings ; the result of the investigation being a belief that, within the coming year, it will be well worth the while of the Board of Trustees to make some unusual effort to secure this object. We are prepared to go even further than this, and state it as our settled conviction, that unless such an effort be made, and *successfully* made, the Institute will be compelled to submit to a serious loss of patronage and prestige, by the superior claims of other institutions, which are making most strenuous efforts to preoccupy this field. While other institutions are making rapid progress, the Rensselaer cannot afford to stand still. Hitherto it has sustained both its reputation and its patronage, by keeping itself courageously at the head of all American technical schools,—or rather by being almost the only technical school in the land, and assuredly the only one maintaining a standard of scholarship at all comparable to those of European schools. Whenever it permits, either voluntarily or by compulsion, any other institution to wrest from it that supremacy, it must begin to decline. Your committee therefore believe that the establishment of this course is, in a certain sense, compulsory, as will appear from the following considerations. Hitherto the Institute has never suffered from want of patronage, because it was without any formidable competitor. Throughout the United States, no school has ever taught civil engineering with equal efficiency, and no school has ever had an equal reputation in that specialty. But in the coming year, both Yale and Harvard will issue programmes of courses in civil, mechanical and mining engineering, which will, in most respects, equal, and in some few surpass, the utmost that the Rensselaer can hope to do. In addition to programmes, they will offer an array of museums, models, drawings, and all the paraphernalia of instruction, by the side of which our own will seem contemptible, and a corps of instructors double or treble ours, and of world-wide reputation. These institutions would long since have been in the field with the same heavy armament, had they not been compelled to fight the battle of science against classics, of things against words, of the new against the old. Thanks to the resistless progress of ideas, the new education has fairly conquered a recognition, full and explicit, of the fact, that science and the useful arts constitute a culture, an endowment and qualification most certainly not inferior to the highest boast of the old regime ; and the same power of inherent worth and native strength will, in a few years, utterly discrown its old adversary and usurp its supremacy. But the recognition of equality is perhaps sufficient for present purposes, and is a victory whose advantages are as great as can be immediately utilized.

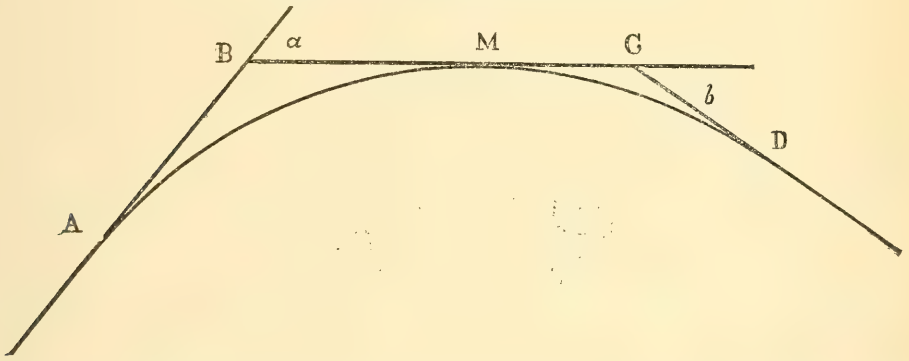
All this may be said to be achieved at Harvard and Yale within a year, and the leaders of scientific thought, who generalled the campaign, are already on the move to push their victory to its last results, which must necessarily be the establishment of first-class technical

schools. They have already been endowed, but have well-grounded hopes of still more munificent donations. The courses marked out are comprehensive, flexible, and thorough, as befit such famous institutions.

While prosecuting their inquiries regarding a school of mechanical engineering, your committee have become convinced that the whole subject has been, heretofore, for the want of thorough investigation, somewhat misapprehended by teachers as well as by the public. The scope and possibilities, and hence the usefulness of such a school, do not seem to have been fully appreciated, and the impracticabilities in the way of its success, such as costly apparatus, an unduly protracted course, and the difficulties of teaching applied mechanics by means of books and lectures, appear to have been unduly magnified. Your committee therefore plead, not only the importance of the subject, but its novelty and the unsettled state of opinion regarding it, as a reason for its somewhat extended consideration in this report, in the hope, not of finally settling the principles and conduct of such a course of instruction, but of removing some of the difficulties in the way of its successful establishment.

[TO BE CONTINUED.]

A NOTE ON RAILWAY CURVES.



The limit to the length of radius of a railway curve is frequently fixed by the proximity of the next curve; this is specially the case in rough sections.

The maximum value admissible in such cases is that of a radius common to both curves, or rather of a curve drawn to three tangents.

The radius and tangent points are readily found, as follows:

Let r = the radius.
" d = A B = B M.
" l = B C the length of the middle tangent.
then $l - d$ = M C = C D.

Now $r = \frac{d}{\text{tang } \frac{1}{2} a}$ for the arc A M, and $r = \frac{l-d}{\text{tang } \frac{1}{2} b}$ for the arc M D.

But these two values are to be equal, hence $\frac{d}{\text{tang } \frac{1}{2} a} = \frac{l-d}{\text{tang } \frac{1}{2} b}$; from which we get $d = \frac{l \text{ tang } \frac{1}{2} a}{\text{tang } \frac{1}{2} a + \text{tang } \frac{1}{2} b}$, which determines the points A and M, and r which is equal to $\frac{d}{\text{tang } \frac{1}{2} a} = \frac{l}{\text{tang } \frac{1}{2} a + \text{tang } \frac{1}{2} b}$.

The method applies also when the curve reverses at the middle tangent point.

When it is desirable to have a certain length of tangent between the end of the first arc and the beginning of the second, this length must be subtracted from the middle tangent, and the remainder taken as the value of l.

THE "filling in" to the chamber of the caisson of the East River Bridge will commence shortly. The excavation is about completed.

THE BOUNDARIES OF SCIENTIFIC KNOWLEDGE.

From "The Mechanics' Magazine."

The lecture on "The Scientific Use of the Imagination," delivered by Professor Tyndall in Liverpool before the British Association, harps upon a subject which also claimed the attention of Professor Huxley, Mr. J. Clerk Maxwell, F.R.S., and Professor Roscoe, F.R.S., in their respective presidential addresses. All of them expressed the desire to see more of the constitution of common matter than the microscope is competent to reveal. All the leading philosophers of the day agree, perhaps without an exception, that light consists of wave motion of the interstellar ether, the evidence being now irresistible, but they are not so well agreed that common matter consists of vibrating rigid atoms. Professor Tyndall brought one splendid idea to bear with great force on the latter subject. He said, in effect, that when waves of sound strike the ear, if we trace those waves to their origin, we always come to a vibrating string, or tongue, or substance, originating the impulses in the air. When mechanical waves of light strike the eye, if we trace out those waves to their origin, how can we expect to find anything but substantial vibrating particles producing the wave motion? Again, it is absolutely certain that the components of common matter, whatever they may be, are in constant motion.

Mr. Clerk Maxwell, Mr. J. Johnstone Stoney, and other philosophers, have spoken much at the British Association of the "vortex atom" speculation, originated by Sir William Thomson; but as none of the speakers at Liverpool explained to the listeners the nature of the idea, perhaps a few particulars given here will be of interest. Helmholtz demonstrated by mathematics that if a "perfect" fluid—that is to say, a fluid destitute of viscosity or fluid friction—were once thrown into a state of *wirbel bewegung*, or vortex motion, it must of necessity preserve that motion to all eternity. Sir William Thomson, taking up this idea, suggested that atoms might be vortex rings of that nature. He and Professor Tait then devised a very remarkable experiment. As they could not get command of a perfect fluid, they were obliged to choose an imperfect one—common air—and then they found means to throw it into vortex rings. They took a large square box and cut a hole as big as a cheese plate in one end; they then cut the opposite end of the box away entirely, and tied a cloth on to its place. Then every time they banged the cloth with the hand at one end of the box, a vortex ring of air was driven out at the other. How were these rings to be made visible to the eye? They filled the box with white smoke by allowing hydrochloric acid gas to enter the box through one little hole in the side, and ammoniacal gas in excess to enter through another; when these two gasses mixed they formed a dense white smoke, so that every time the cloth was struck, out flew a vortex ring of air holding white smoke in suspension. The white rings floated about the room and lasted for some little time, but, air not being a perfect fluid, they finally melted away. It was a curious sight to see two of these rings come into collision in the room, for then they rebounded from each other like india-rubber belts.

This article is headed "The Boundaries of Scientific Knowledge;" and there is another field of mystery which enters much into the consideration of the philosophical mind, but which was not brought under the notice of any section of the British Association. That subject is, the numerous instances in which solid objects rise or float in the air by some force having no weight of itself, yet competent to overcome the attraction of gravitation. Professor Tyndall recently exhibited a case of this kind at the Royal Institution, when he showed two little fishes cut out of gold leaf quivering in the air near the knob of a charged Leyden jar. What held those fishes there? "Electricity," is the ready reply. Yes; but electricity has no weight; so here is a clear case of "something" without weight supporting in the air metallic gold, one of the heaviest of the metals. The said "something" was also invisible by daylight, though had the light been shut out a beautiful brush-like electrical discharge would have been seen emanating from the pointed tails of each of the two fishes. Magnetism likewise, as everybody knows, will cause a

piece of iron to rise in the air in opposition to the attraction of the earth, and this phenomenon is at the present time perfectly inexplicable by the man of science.

A very interesting experiment connected with this subject was recently performed at the telegraphic soirée given at the house of Mr. John Pender, on the occasion of the opening of direct electrical communication with India; the Prince of Wales, it may be remembered, was present on the occasion. As the experiment is a new one, and the details have not as yet, we think, been published in any journal, it may be of interest to many men of science if we publish them here. Lord Lindsay had at the soirée an enormously powerful electro-magnet, with adjuncts to facilitate experiments in diamagnetism. The poles of the magnet were square and two inches across, and when a half-crown was allowed to fall through the air between these poles it took four seconds to fall through the two inches of space containing nothing possessing weight except common air. This is a common enough experiment, but Mr. C. F. Varley, C. E., the electrician, devised a novel experiment to show that the magnetic rays do not hold up the half-crown, but generate electrical currents to produce the effect. He had some copper wires bent into rings and soldered together; the wire was 1-16th of an inch in diameter, and the ring 1¼in. These rings were seven seconds in falling through the two inches of magnetism, but on breaking the soldered junction, and thus preventing the well-known formation of electrical currents therein, the ring fell through the space very rapidly. Mr. Varley concludes that this experiment proves "that a current of electricity is as solid and material to a magnetic field as is a plate of iron to a bar of copper." The general subject of the suspension of solid substances in the air, in opposition to the attraction of the earth, and by invisible forces, or perhaps substances having no weight of their own, is worth consideration in one of the sections of the British Association next year.

RAINFALL—ITS VARIATION WITH ELEVATION OF THE GAUGE.

By CHAS. CHAMBERS, F. R. S.

From "The Engineer."

The fact is well-known to meteorologists that the quantities of rain received in gauges placed at different heights above the ground diminish as the elevation of the gauge increases. Several attempts have been made to explain this phenomenon, but none of them are so satisfactory as to discourage the search for other causes that may contribute substantially or mainly to its production. Hence the submission for the consideration of the British Association of this further attempt. One of the principal causes of rain is undoubtedly the transfer, effected by winds, of air charged with moisture in a warm damp district to a colder region, where the vapor it contains is partially condensed. The temperature of the lower as well as of the higher horizontal strata of the air being reduced by this transfer, it may fairly be inferred that condensation of vapor will also occur in the lower as well as in the higher strata. The rain caught by a gauge at any given elevation will therefore be the sum of the condensations in all the strata above it, and thus the lower a gauge is placed the greater will be the quantity of rain received by it. Again, it is known by observation that there is at all times a greater or less difference of electrical tension between the atmosphere and the surface of the ground. If, then, in accordance with the views of Professor Andrews as to the continuity of the liquid and gaseous states of matter, from which it follows that the change of other physical properties must also be continuous, we regard the particles of vapor suspended in the air as electric bodies in relation to the dielectric principal constituents of the atmosphere, they will be polarized by induction from the electricity of the ground. This polarization will give rise to an attraction between every particle and the neighboring particles above and below it; and being stronger in the particles nearer the ground than those more

remote, the tendency of the particles to coalesce—which will increase by their mutual induction as two neighbors approach each other—will be greatest near the ground. Thus it may be—each particle gathering to itself its neighbors successively till their united density exceeds that of the atmosphere generally—that some rain drops are formed, and that in greatest abundance near the ground. If this be the true cause of any substantial part of the phenomenon in question, then, as the variation of intensity of electrical polarization of the particles will vary with height most rapidly near the ground, so the variation in the rainfall near the ground should be more rapid than at a greater elevation; and such is indeed the fact.

Also, if the idea be correct, it will probably serve to explain other phenomena which it was not specially conceived to meet; and so it does. For, first, it requires that the rainfall over even ground, when the electrical tension is relatively weak, should be less than over similarly situated forest land, where at the tops of the trees, ends of branches, and edges of leaves, the tension is high; and this is in accordance with observation. And, secondly, the tension being relatively high at the tops of the elevations of a mountainous district, the rainfall should be greater there than in the neighboring plains; this again is borne out by observation. Further, at the commencement of a passing thunderstorm, a sudden heavy shower of rain will often fall for a few moments, and then suddenly cease. May not this arise from the approach, by the agency of opposite wind currents, of detached masses of oppositely charged clouds—the process just described of formation of raindrops going on rapidly in each mass as the two come near each other, and stopping when by a flash of lightning between them the two masses are brought into the same electrical condition. An experimental test of this idea would be to repeat Dalton's measures of the pressure of vapor in the vacuum space of a mercurial barometer tube, filling that space with air and a little water; and compare the values found when the mercury was charged with electricity, and when not so charged. If in the former case a less pressure was found, we might conclude that the particles of vapor are really susceptible of electric induction; and the amount of difference existing would enable us to estimate whether the attraction of the particles upon each other were strong enough to cause the formation of raindrops hypothetically attributed to them above.

SUBMARINE BLASTING.

A paper read before the Am. Society of Civil Engineers by F. Collingwood, C. E. gives the following:—

In excavating for the foundation of the Brooklyn pier of the East River Bridge, the bottom was found to have, running about through the centre of the excavation, a ridge of exceedingly hard material, being composed of boulders of all sizes imbedded in compact clay.

As the dredges would scarcely scratch the botttom after this was reached, the following method of loosening it was adopted:

A solid iron pile, 18 ft. long and 5 in. diameter, shod with steel, with a ring at the upper end for hoisting, was driven by an ordinary pile-driver down to the desired depth. On withdrawing it, it was found that a perfect hole was left, into which a tin canister containing 13 lbs. of powder was easily inserted. The effect of the charge was to leave a crater reaching at the centre below the desired bottom. The success of the experiments was so decided that another pile of 5 in. diameter and 22 ft. long, and one 6 in. diameter and 22 ft. long, were procured. By the aid of these, with 2 pile-drivers and crews, and a diver and assistants, from 20 to 40 blasts per day were fired at a depth of 18 ft. below mean high tide.

The dredge was able (after the bottom had been gone over in this way) to excavate from 50 to 120 yards per day.

The material was from 2 ft. to 8 ft. deep.

Time of driving about 5 minutes.

Cost probably about $3 to $4 per cubic yard.

When the pile fastened between two boulders it had to be loosened by blasting round it.

The economy of the operation as compared with the usual method of drilling is very decided.

TIMBER AND CONSTRUCTION.

From "The Builder."

One architectural characteristic of the present day is the substitution of iron for various materials used in construction down to the earlier portion of the nineteenth century. The origin of the change was not of an architectural nature. It was neither the destruction of forests, the loss of skill, the sudden discovery of any new material, or property of a material, or any of those changes to which we are accustomed to attribute the previous modifications in the form of Christian architecture. But the seed and principle of the new style is referable to the fact that, some sixty years after Watt has first learned how to derive motive power from the expansion of water by heat, a colliery laborer succeeded in applying that same power to the propulsion of carriages by land.

With the construction of the Liverpool and Manchester Railway, in 1828 and 1829, an entirely new era was inaugurated. Structural requirements were altered, and the effect of the alteration very soon became evident in monumental form. With an increased facility for the transmission of heavy weights over lines of iron rail, a demand for an improved mode of bridging over rivers, roads, or other openings, sprang up. The supply and the manufacture of iron thus received a stimulus, and the iron trade, in its turn, reacted upon the designs of the architect and of the naval constructor, by giving him a material which was virtually a new one. Men of practical mechanical genius first labored to produce structures of wrought iron of which the expense should be reduced to a minimum. Thus Sir Charles Fox, then a subaltern of Robert Stephenson, designed that simple, inexpensive shed roof, for the Euston square passenger station, which for some time was the normal type of similar structures. The taste and lavish expenditure of Isambard Kingdom Brunel next produced the Great Western Station at Paddington. The need of bridging the Menai Straits led to the construction of the hollow box girder, and the piercing of London with railways induced the execution of those effective, but hideous bridges, the aspect of which so afflicts the man of taste. Soon the displacement of architectural requisites by structural combinations that took no heed of any laws but those of strength, spread from the floor to the roof—from the bridge to the station ; and men vied with one another in the erection of the largest, the most unnecessarily costly, and the most hideously unarchitectural forms that the world has yet seen.

The use of iron for railway purposes has crept in, to an extent constantly increasing, in civil buildings. Vast shop and warehouse fronts of iron are filled with plate glass. Permanent exhibition buildings are erected, of that perishable combination of iron, glass, and wood, which may answer, on a small scale, for a conservatory, but which is the most costly style of structure, as far as maintenance goes, of which we have any experience. Connected with the same increased energy in our workshops are the increase in the power of artillery, the improvements in the manufacture of shot, the launching of iron and steel armored vessels, and the construction of shields for fortresses, as to which, at the present moment, the art of defence is somewhat ahead of the art of attack.

Concurrently with this substitution of iron for wood, and for other materials, there has been, with very few exceptions, a wanton waste of the forest resources, not only of our own country, but of the entire world. Man has come to regard his early cradle, the forest, as an enemy, instead of a benefactor. In England the prudent care of our forefathers to watch the growth of our forest trees—to secure a perennial supply of oak for our ships, as well as of yew for our bows, is altogether forgotten. The forest rights of the crown over a district that has been wooded since the time of Julius Cæsar—the forest of Epping—have been so purposely neglected, that it has needed the very unmistakable expression of public feeling to elicit from the Solicitor-General anything more than a joke upon wolves and bears. The 100,000 acres of forest, under the administration of the Woods and Forests, has been so admirably managed, as to arrive at the result of a rental, at the rate of 3s. 6d. (three shillings and six-pence) per acre. The wooden walls of old England are now

so much an affair of the past, that it may be said that we only regard timber as necessary to ornamental landscape, or as a material for lucifer matches.

It is in this country and its dependencies, and in those of our American descendants, that the laws of Nature, as to the clothing of the earth with timber, have been the most persistently broken. But we are far from being alone in our folly. To whatever part of the world we turn we see indications that waste and destruction bring their own vengeance in their train. Of the effects produced upon climate by the denudation of the soil, there is no room for doubt. To a certain extent the influence of human labor in the thinning of forests is beneficial. But the limits between culture and destruction are rarely maintained. In the year 1816 the forest came up close to Philadelphia. The Delaware, a mile wide, was then often frozen in a single night. The edge of the forest has receded to a distance of more than thirty miles. The thermometer is now rarely down to zero ; the river is hardly ever frozen ; nor does snow lie long on the ground. In the forest it lies very long. The increased aridity of Palestine, of Spain, and of the south of France, is well known. In the former case it has been partly caused by the cutting down of the olive, a barbarous incident of warfare, merely forbidden by ancient law. In the last-named country it has been the need of fuel that has led to the denudation of so many districts, and the double evil has ensued : first, that the humidity of the climate has been reduced to a formidable extent ; and, secondly, that when rain does fall, in any unusual proportions, the absence of the great natural absorbing power of forest districts allows the entire product of the rainfall to be discharged at once by the natural drainage, thus causing those floods which have proved so formidable in their ravages within the last few years.

The denudation of the forests of England is by no means a new grief. More than 200 years ago Mr. Evelyn complained of the rapid extirpation, "root and branch, of all those goodly forests and woods which our more prudent ancestors left standing for the ornament and service of their country." On the confiscation of the Church lands, in 1536, immense forests were cut down ; and during the civil war that commenced a century later, many royal forests, as well as private woods, were entirely swept away. In France there yet exist 2,700,000 acres of State forest, earning a gross revenue of £1,740,000 and a net revenue of £1,240,000 per annum. Bavaria contains nearly 2,000,000 acres of forest ; Prussia, upwards of 5,000,000 ; Austria, no less than 13,000,000 acres, realizing an annual export value of £3,000,000 sterling.

In France and in Germany exist schools of forestry in connection with the service of the State, and men of a superior class of intelligence are carefully trained in these establishments for the scientific management of this important part of the national property.

In Bavaria there is a school of forestry at Aschaffenberg on the Maine. The candidates for admission must have passed good examinations in the higher public schools. The time of training extends over five years, half of which time is devoted to acquiring a practical acquaintance with the condition and the care of the forests of the State. The special scientific course comprises lectures on forestry, management of forests, planting, division of forests into blocks, valuation surveys, rotation of classes of timber, and the due rotation between the maximum yield of a forest, and its maintenance in an uninjured condition. Preparation, transport, and sale of forest produce, form another special branch of study. Botany, chemistry, zoology, physiology of plants, climate, and geographical distribution of plants, form the natural science division of the course ; and mathematics, pure and applied, engineering, surveying, and forest legislation complete the *curriculum*. On passing the final examination, the students are qualified for appointments in the Bavarian forest service.

In France a similar college exists at Nancy, where from thirty to forty students are trained for the service of the State. The service is directed by the "Bureau Central de l'Administration générale des Forêts," and 849 *conservateurs* and *inspecteurs*, having under their orders 3,500 *gardes gènèraux*, have charge of the public forests of France.

Forest schools are also established at Hanover, Newstadt, Eberswald, near Berlin, Thurant, in Saxony, Eisenach, and

other places in countries possessing State forests.

The threatened and very proximate exhaustion of the enormous forests and timber-growing jungles under the British rule in India has led to a tardy attention being paid to this important subject by the Indian Government.

From the report of Dr. Brandis, Inspector General of Forests in India, it appears that the normal average of first-class teak trees in a virgin forest is fourteen per acre. A teak forest at Maulmain, in the hands of the Government, extending over 550 square miles, has been found to contain only three full-grown trees in two acres, while damaged trees and stumps abound.

Forests of the Sâl or Saul tree replace those of teak in Central India, to the north of the Nerbudda river. A belt of forest, from five to twenty miles wide, extends for a length of 1,500 miles along the foot of the sub-Himalayan range, and up to an elevation of 3,000 ft. The Saul tree grows socially, and by its dark green foliage excludes the growth of other trees ; being unlike the teak in this habit of growth. In Oude and Nepal the jungles contain as many as seventy first-class trees per acre, together with from 200 to 300 of all sizes, springing up from seed. The system of letting these forests by contract in annual leases to the highest bidder, while bringing in a positively insignificant return, has had the effect of stripping all the accessible parts of this large district of full-grown trees. Such is the size attained by this noble tree, which, with a specific gravity less than that of the oak, possesses from one and a half times to twice the strength of that wood, that the Nepal ferry-boats, used to contain from ten to fifteen men, with horses and cattle, are hollowed out of single logs. The tree takes about 100 years to arrive at this size The British Sâl forests are computed to cover more than 3,500 square miles, and a rest of forty or fifty years will be requisite to replace this waste of first-class trees which has been so blindly permitted to go on.

From the state of the Sâl forests it may be concluded what is the condition of the supply of teak, a tree which grows so much more sparely in its natural home. In 1822 the forests which the native princes had studiously preserved were thrown open to the public. Within eight years it was discovered that, owing to indiscriminate cutting, teak timber fit for Government purposes was growing scarce, both in Madras and in Bombay. In 1839 Mr. Williams, the dockyard manager, reported, that within 21 months 40,000 teak-trees, between 12 in. and 6 in. in diameter, had been floated down by the contractors, whose indiscriminate waste was thus destroying the resources of the future. So great had been the destruction, that in 1842 the Government actually purchased 260 sq. miles of forest land, for replanting with young teak, for the use of the dockyards. It was found that the expense of thus preparing a single acre of forest nursery was greater than the value of the timber which could be grown on a sq. mile in 100 years! During the 20 years preceding this futile attempt to repair irreparable waste, the forests of Malabar, Canara, Goojerat, Bombay, Madras, Rajamunduy, Coimbatore, and Cochin, stocked with first-class trees fit to cut, and with an ample supply of young trees in all stages of growth, had been given over to destruction. The contractors took no heed of those who might come after them, and cut everything that came to hand.

During this time the forests of the Rajah of Travancore, under the charge of an English conservator, had yielded a regular revenue, while still containing a full supply of first-class trees. For every 10 trees fit to cut, 2 were left for seed ; and for every tree actually felled, 10 were planted.

The teak-growing districts of Burmah extend over more than 7,000 sq. miles of forest. A system of well-devised management has been introduced into this district, in 1858, by the conservator, Dr. Brandis. The forests are divided into 6 divisions, of upwards of 1,000 sq. miles each, containing an estimated number of 100,000 trees in each district. The trees are divided into 5 classes, each individual tree being allowed a period of 24 years in each class, thus making the total life of the tree, from the germination of the seed to the felling of the timber, 120 years. The ordinary average of the forest gave 100 trees of the first, second, and third classes, and 200 of the fourth class, per mile. By cutting, therefore, only 80 of the first class in 24 years the forest is uninjured, and in the course of 120

years its stock of timber is entirely replenished.

The specific gravity of green teak is greater than that of water. The dry timber, on the other hand, will float. It is therefore the practice to mark and girdle the trees 3 years before felling. The tr e is killed by the destruction of its bark, and dies *in situ*. When felled it is dragged to the rivers by elephants, and floated down to Rangoon, the Government paying so much a log on its arrival. Under these arrangements the Burmese forests have kept up a good supply of timber without exhaustion, and have insured an annual profit to the Government of £60,000, besides providing for the expenses of their own conservation, amounting to more than £30,000 a year.

No less important than the conservation of our extensive forests, inexhaustible as they may prove under prop r management, although readily destructible by the waste which we have been accustomed to allow, or rather to practise, is the introduction to the knowledge of the English builder and manufacturer, of those noble and beautiful species of wood of which we command so great a variety. It is incredible to what an extent this part of the subject has been neglected. At the Paris Exhibition of 1867, timber from no less than 3,769 distinct species of trees was collected from forty-five different countries. Of this large number Europe contributed 395 species. Africa yielded only 252, showing that the resources of that large continent were almost virgin. Asia produced 858 species, Oceania 966, and America no less than 1,298.

Among the most notable of these materials for the builder may be mentioned the Eucalyptus Amygdalina, from Victoria, which attains in the valleys of Daudemony and on the Yarra river the height of 420 ft. Dr. Mueller says that this amazing height is by no means exceptional, and that it is due rather to great rapidity of growth than to extreme age. The "white gum" (Eucalyptus Stuartiana), and the "stringy bark" (Eucalyptus obliqua), are said to exceed 300 ft. in height, and to cover the plains and more barren mountains of Victoria. From the same vicinity come beautiful ornamental woods. The Senecio Bedfordii, a curious striped wood, and the Banksia serrata, marked with a patern like network. Gipps Land produces the Eucalyptus longifolia, said to last in the ground for twenty years, and the Acacia supporosa, an elastic wood resembling hickory, and yielding straight spars from 50 to 100 ft. long.

British Guiana produces the "Greenheart" (Nectandra Rodeii), called by the natives Sipicu, a timber which is remarkable both for its great durability and for its extraordinary strength, which is three times that of oak. Balks of this timber, squaring from 18 to 24 in., may be had from 60 ft. to 70 ft. long without a knot. In the same locality, the mora (Mora excelsa) attains a majestic height of from 100 ft. to 150 ft. It is so tough that it is sure not to splinter when struck by cannon shot. Its strength is more than double that of oak, and it is said to be exempt from dry rot. Of the seven species of timber which form the first class in Lloyd's classification for shipbuilding, oak, which heads the list, seems to be far inferior to the East Indian, the Australian, and the African timber, to which we have referred. The list includes seven species of timber, the ordinary European oak (Quercus robur), the live oak of North America (Quercus virens), African oak (Quercus Africana), teak (Tectona grandis), and sal (Shorea robusta], from East India; mora (Mora excelsa) and greenheart (Nectandra Rodeii) from British Guiana, and iron-back (Eucalyptus, species not named) from Australia.

It is beyond the limits of our space to describe the varied, mottled, striped, and colored woods which offer such admirable materials for the artist, whether for furniture, for doors, skirtings, and wainscotings, or for inlay work. The use of dyed or stained wood for the latter is rendered unnecessary by the bounty of nature. From the pure white of satin wood, and of numerous other species, to the full lustrous black of ebony, we can simulate almost any that form the resources of the vegetable world. French Guiana produces a violet wood of extreme beauty, the "Bois violet" (Copaifera bractata), and the Caryocar glabrum, a splendid yellow timber. Brazil has a red wood fit for any kind of furniture, the "Echrospermum Balkasarii," and the Dalbergia nigra, a beautiful rosewood. Venezuela has a zebra wood (Cordia zebra); Natal produces sneezewood (Pteroxylon utile), equal

in beauty of grain to the best bird's-eye maple; Canada, its white and pencil cedars (Thuja and Juniperus Virginiana).

It is needless to refer to the ec nomic products of the forests, apart from the actual timber: turpentine, resin, Burgundy pitch from the pine forests of the Lauder; cork from the south of France, Corsica, Algeria, Italy, and Spain; gum animi from Zanzibar; gum copal from Angola and Sierra Leone; gum acacia from Senegal and Mogador; gum arabic from different sources; palm, cocoanut, and other vegetable oils; coir and fibre; bark for tanning; osier and bamboo; corozo, or vegetable ivory, and nuts for turners' work (Phytelephas macrocarpa) from Ecuador; the vegetable wax of the Carnauba palm (Corypha cerifera) from Brazil; caoutchouc, the milky sap of the Siphonia elastica, and other elastic gums, as well as logwood (Hæmatoxylon campechianum), and other dye woods from the same rich vegetable district; bark mat from the bark of the lime, the Russian source of supply for cordage, bags, mats, sandals, bassets, horse-collars, packing-cloths, and other purposes; black and gray moss from Louisiana, used by upholsterers for stuffing; "forest wood" for the same purpose, formed from the needle-like leaves of the pine, essential oil from the same tree, balsam and spice. Such are but a few of what may be called the incidental products of the forest.

Our purpose will have been accomplished if we have succeeded in awakening attention, first to the fact of the invaluable stimulus to art in all its branches, no less than to civil and naval architecture, that must result from the attainment of a competent knowledge of the vegetable kingdom; and, secondly, of the absolute importance, as a branch of the great profession of which the architect, the engineer, the shipwright, and the surveyor, are alike essential members, of the intelligent study of forestry.

FIELD ARTILLERY.

From "Engineering."

We observe, with much satisfaction, that the "Times" has hit the right nail on the head, and hit it vigorously, in its article on French Field Artillery. The article is not the less valuable on account of the fact that in these days of steel and Whitworth metal, bronze has been reverted to by our Government for Indian field guns, and an attempt has been made, not altogether, we believe, without success, to bring us back to bronze field guns in our own army. The chief advocate of the bronze field gun is, we believe, Colonel H. H. Maxwell, R. A., who as the head of the Cossipore Foundry in India, might possibly find his office abolished if new work were not found, and is therefore to be admired for his energy in the matter. With Colonel Maxwell has been associated a few other military gentlemen, forming together a committee, who have settled the matter for us, and persuaded Mr. Cardwell and Lord Northbrook that bronze—a metal of about 17 tons strength to the square inch, at its best, and very liable to failure in casting—is decidedly the best material for guns at present; not, be it understood, for big guns, nor yet for little ones; but for guns of the peculiar size of field guns! A bronze rifle would probably strike ministers as a thing a little out of date; and it is possible that bronze 300-pounders or 600-pounders might do the same; but for field guns, what, ye engineers, can you have better than bronze? We must do Colonel Maxwell the justice to say, however, that not only is he not afraid of being thought a little antiquated in his notions, he is rather disposed to boast of the fact; at least, he thinks other people will find it amusing to see what old-fashioned notions he forms, and gets the Government to adopt, on his advice. Let the reader note well the last two sentences of the following passage from a lecture of his on the subject, at the United Service Institution, which we italicise for the reader's convenience:

"In the present state of our knowledge, the choice of a metal, or combination of metals, for a field gun, appears to lie between steel or steel protected by a wrought iron coil, and bronze. Circumstances may have unduly prejudiced me" [a very candid and proper admission, no doubt],

"but I confess I think there is nothing like bronze for the roughing of a long campaign, nothing like it for simplicity of manufacture, nor for safety from bursting, nor, finally, for economy. *It is curious to look back and to find that I am expressing an opinion held as far back as four and a half centuries. One Capo Bianco, publishing in* 1589, *states that there were bronze guns in existence in* 1418."

We entirely agree with Colonel Maxwell. It is curious—very curious, almost painfully curious—to look back and find that even in four centuries and a half we have made, according to the ideas of a colonel, a military committee, and a British Government, no progress in the production of metals for the manufacture of guns. We wonder if Colonel Maxwell and his patrons have ever heard of the "flint implements" which were used very much longer ago still, for various mechanical purposes. He might, with admirable consistency, provide for the use of flint tools in the erection of the new bronze gun machinery, and then he could write another paper, and tell the great modern engineering world that it would be curious to look back and find that he is now expressing opinions" held as far back s the dateless period of antiquity compared with which one Capo Bianco would be a gentleman of yesterday.

We are obliged, however, to question Colonel Maxwell's opinions in spite of their curious antiquity. In the first place, "the roughing of a long campaign does not appear to us to be the first thing to provide for in modern field guns for European armies. What is primarily wanted is a gun firing projectiles of great range, accuracy, low flight, and what the "Times" (in translating *conservation de la vitesse*) well expresses as "the quality of keeping up the power to hit hard throughout its flight." Even the most casual reader of the reports of the war now raging must have observed that over and over again the opportunity has been afforded, and as often lost, at least by the French, of directing a deadly fire upon the enemy at very long distances. But the French gun is too weak to admit of advantage being taken in these places. The way to get the advantage in such cases is to fire a long shell with the largest powder charge that the gun can consume in its bore. When the gun is strong enough to stand this, you get the range required, in combination with great accuracy, low flight, and great penetration, or a hard blow. But the bronze gun cannot stand it; it is of less than half the strength of the steel gun, and the consequence is that a light shell, which flies high and not very accurately, and is spent before it reaches far, is the only projectile that you dare to fire from it. We are in possession of the report to which the "Times" article refers, and we find these points brought out in it even more strongly than in that article, which we republish on another page. For example, suppose you wish to obtain a range of about two miles. With the French bronze gun you have to give an elevation of about 20 deg., and consequently fire your shell 420 metres high into the air in order to make it reach the distance, and when it does reach, its velocity has dropped from 343 metres per second to 160 metres. The Whitworth ten-pounder steel gun, on the contrary, in order to obtain the same range, has only to be fired with an elevation about 10 deg., and consequently never rises higher than about 180 metres, and when it reaches the two mile distance retains a velocity of 257 metres per second. Military men ought to be the first to secure such overwhelming advantages as these steel guns present, and they would be the first, if they cared less for the past and more for the future.

Colonel Maxwell is equally wrong as to the simplicity of construction of the bronze gun. The successful casting of a number of bronze guns is not by any means a simple matter; and in proof of this we may state that attempts are now being made at Woolwich arsenal to get over the difficulties which attend the manufacture. And partly on account of these very difficulties, it is equally a mistake to suppose that these bronze guns are economical. They are not so; on the contrary, their manufacture is a very wasteful process. A great number of failures in casting occur; a large quantity of metal in excess of the actual weight of the gun—sometimes three times that weight—has to be melted and cast every time a gun is made; and this metal cannot be used over again without an addition of at least 10 per cent. of new metal. The process of casting bronze guns is, in fact, a costly and

uncertain process compared with the manufacture of a gun of Whitworth metal, and this metal, like bronze, can be melted down again as scrap hereafter. The idea that bronze is safer against bursting than the Whitworth metal is absolutely an error, and entirely inconsistent with facts which we and other scientific journals have stated upon the subject.

The fact is, we can make progress in this country in materials and in manufactures—of guns as of everything else ; but what it is hard to make way against is that stupidity of the Government which continually invests military men with responsibilities upon questions which they do not understand, and that incapability of the military mind in England—of course with numerous exceptions—to comprehend the real nature and consequences of great improvements until they have first seen them adopted and put in action elsewhere. Their eyes are in the backs of their heads.

BOILER EXPLOSIONS.

From "The Mechanics' Magazine."

Perhaps the most difficult code of laws to enact for the inhabitants of a free country are those whose object is to compel people to take care of their own lives and properties. It is impossible, for example, in a country like Great Britain to enact a statute against extravagance, and where a man comes in for a fortune a portion of his prerogative as a citizen lies in the fact that he may squander his property in such manner as best pleases him. Were this principle confined alone to money matters, or any matters apart from danger to human life, all might be well ; but it is not so confined, and as the law so stands at present an employer of labor in many departments of industry may by either his carelessness, his parsimony, or his ignorance, endanger the lives and limbs of his employés without incurring much risk of being called to account in the event of a disaster.

For several years after the introduction of steam as a prime mover it was generally thought, even by clever professional men, that there was something occult, something mysterious, in a boiler explosion ; papers were read, pamphlets and books written and published, each and all on this theme, and originating for discussion sundry theories more or less elaborate as to the causes of these explosions. Matters of late years, however, are gradually assuming another aspect. The possibility of so simple a supposition as that boiler explosions, in nine cases out of ten, were easily preventable, begins to receive attention, and the more the subject is investigated the more obvious becomes the plain fact that the inherent causes of these explosions are not to be found in peculiar chemical combinations, spheroidal heat phenomena, etc., but in the placing of a piece of wagon wheel or a bag full of bricks on the safety valve lever, of letting the crowns of the fire-box become red hot, of having boilers "cobbled"—no other word will apply—by any jobber who could knock up a rivet or handle a caulking chisel. Many attempts have been made by Government to remedy this state of things without avail. One great obstacle to legislation consists in the fact that legislation and responsibility in matters of this kind always go together. If Government step into the province of the professional engineer it must assume the responsibilities of the profession, and to do so with safety or efficiency it must obtain the engineer's knowledge and experience. Again, another difficulty in the matter lies in the fact that engineering, of all professions, admits of no fixed rules ; it is impossible to draw up a set of rules that will apply more than partially to this question. For example, it is impossible to prescribe by law the pattern of donkey pump to be used to feed the boiler, and it is a matter of difficulty to provide by law that boilers shall never get short of water, be subjected to over-pressure, or be repaired by incompetent men. Any measures to be adopted in the way of legislation on this subject of explosions must be based on the rules of the existing boiler insurance companies, or consist in the severity of the penalties to be incurred by those to whom responsibility would attach for proved carelessness. There cer-

tainly is one point—we will say two—in ch Government not alone can, but ought to interfere ; the one is the question of responsibility of master *versus* man. In most cases this responsibility attaches exclusively to the former, but not always ; several examples will be found where it attaches to both parties—attaching to the master in the careless employment of incompetent men to work their boilers, and attaching to the men who undertake duties for which they are not duly qualified.

The second point calling long and loudly for change in existing laws is the manner of inquiry into what may be termed scientific diasters, such as boiler explosions. We have no doubt that coroners and coroners' juries honestly try to investigate such things to the best of their abilities, but in these matters ignorance is not bliss, and it is therefore folly not to seek out wisdom. In such matters as come within the Board of Trade rules, scientific evidence under certain conditions may, we believe, be called; but a coroner has no such power. Government will generally send an engineer to the scene of an explosion and receive his evidence, but this plan does not go far enough ; there should in such inquiries be a professional assessor on the bench to assist the coroner, and who should have full power to ask questions; these courts, too, should have power to call more than one scientific witness. Nothing gives professional engineers more disgust than the perusal of the reports of coroners' inquests as at present conducted in dealing with questions of science. The questions that should be asked are not asked, and questions are put that are very foreign to the real point at issue.

That, however difficult the task of legislating on this subject of boiler explosions may be, it yet is one that Government can no longer neglect is patent to all observers. The glaring instances of parsimony, of incompetence, and of reckless carelessness that are reported over and over again show the necessity for some amendment in the law. Take the explosion at Leicester the other day, for example. In that case nothing could exceed the either gross ignorance, or worse still, the criminal carelessness displayed by both those who mounted and those who worked that boiler. The evidence of an engineer proved, first, that the safety valve was too small ; second, that the ratio of the lever did not agree with the area of the valve, so that in the first case the valve, even if properly loaded, could not efficiently relieve the boiler if a heavy fire were on and the engine standing, and in the second case the pressure in the boiler would be much in excess of that shown by the spring balance on the lever when the valve was blowing off. There is no more difficulty in compelling boiler-makers to take out licenses to pursue their trade than there is to make physicians or surgeons or solicitors have licenses. Master mariners and pilots must have certificates of competency, and in the event of miscarriage in their several callings they are liable to have their certificates suspended. There is no reason why this system, suitably modified, should not be applied to the makers, repairers, and users of steam boilers. We see patents again and again secured for improved safety-valves, for improvements in feeding-water, and for sundry other contrivances to diminish the chances of explosion ; but, *cui bono?* so long as the commonest and most obvious provisions against these calamities are persistently neglected. We have had letters from correspondents proposing schemes for improved safety valves, and asking us questions as to the reason why boilers should ever explode if provided with proper ones. Is it not, however, folly to expect that elaborate and costly contrivances will be employed when the plain button valve and steelyard are not used as they should be?

Another important point should receive careful attention from the Commission on Boiler Explosions (one, by the way, which we fervently hope will be reprinted next session of Parliament), that of stays. Only too frequently is this part of a boiler-maker's work most shamefully "scamped," and scamped more and more in proportion as the proposed working pressure is lowered ; in fact, as a rule, high pressure boilers are much more carefully made and worked than are low pressure ones, for the simple reason that pressures of 100 lbs. or 140 lbs. per in. enforce attention in a manner that will take no denial. We have heard of a cylindrical flat-ended boiler of considerable size (some 4 ft. diameter) being worked which had not a single longitudinal stay in it. So bad a boiler, indeed,

was it that a practical boiler-maker, called in to examine it with a view to repairs, instantly left the house and insisted on the fire being there and then withdrawn. The trick of fixing lumps of putty on the proper places to represent stay heads, in order to deceive insurance inspectors, is of common occurrence. Cases of Cornish boilers, whose flue tubes are destitute of angle iron strengthening rings, are by no means uncommon. We might fill columns were we to recite the radical defects existing about boilers, working daily and hourly in the midst of crowded streets and workshops. Are they not written in the reports of boiler inspectors? Many of them, we fear, are beyond the reach of any but penal legislation, it being next to impossible to devise statutes of a preventive nature in the direct sense of the term. Still, although the subject is one attended with difficulty, yet we have gained much in stripping it of everything like scientific superstition, and in demonstrating the fact that steam boilers can be used with nearly perfect safety so long as we take care to observe carefully the laws of nature and of common sense.

ELECTRICITY NOT A DUAL FORCE.

By RICHARD HIGGS, B.A.

From "The Electric Telegraph & Railway Review."

Calorimetry teaches us that heat propagates itself through certain bodies with greater facility than through others. Some bodies likewise transmit electrical force better than others; those offering a ready passage are termed, in electrical science, *conductors*, and those offering a high resistance, *insulators*. Conductors and insulators are the same in kind, but differ in degree. Experiment proves that the best heat conductors are the best conductors of electricity. The following table will show the relative conductivities of the various metals :—

	Electricity. Mathiessen.	Heat. Wiedemann.
Silver	100	100
Copper	77.4	73 6
Gold	55.2	53.2
Sodium	37 4	....
Aluminium	33.8	....
Zinc	27 4	28 1
Potassium	20.8	....
Iron	14 4	11.9
Tin	11.4	15
Platinum	10 5	8.4
Lead	7 7	8.5
German Silver	7 7	6 3
Antimony	4.3	....
Mercury	1.6	....
Bismuth	1 2	....

It will be seen that they generally agree as to order, but differ as to numerical relation. This difference may be accounted for by variations in the purity of the metals tested. The similarity in conductivity shows that electrical-force and heat-force are nearly allied. There then remain two theories by which we may explain the transmission of electrical force. Heat is supposed by most physicists to be the *result of the vibration or motion* of the atomic particles composing bodies, and this vibration produces the sensation of heat to our nerves. So far it is easy to follow the theory, but it is further stated that the vibrations which cause heat, take place not only among the atoms of which bodies are composed, but also in an ether supposed to surround each atom. This is difficult to understand, for if we consider gases or air to be made up of atoms, it is next to impossible to suppose that there is some intermolecular medium not made up of atoms, and which is yet not vacuous space, even though we may name it, mysteriously, ether. The other theory is that so ably raised in reply to Faraday's objection, that if space be vacuous it must be an insulator, and there can be no transmission of electricity from particle to particle, and that therefore space must conduct. It has been answered that "if space be an insulator, and if a conducting atom charged with electricity can move through space into contact with another conducting atom, then there can be a transmission of electricity from atom to atom." * In proof of this theory experiment has shown that, in liquids and solids subjected to electrical currents, there is molecular motion.

* Electricity and the Correlations of Electrical Force. Desmond G. Fitzgerald.

We have next to consider the kind of motion imparted to each atom, and here we must be content with theory alone. It can be inductively reasoned that the motion is circular, for as we conceive an atom to be circular in form, we must suppose it to follow the general law that when motion has been imparted to a spherical body, it revolves on its own axis in a direction answering to the line of force; a cannon ball revolves in its passage through the air, and the earth itself in its passage through space. Regarding a conducting wire as a line of atoms, we know that if motion is imparted to one end of the line, it will be transmitted to each succeeding atom till the distant end is reached. Let the reader take a dozen marbles, and place them in a line in the groove formed between the pages of an open book; let the nearest marble be struck, and the motion will be transmitted to the whole line, the last marble rolling some distance away. Let a spring that will always give the same force be arranged, and let the number of marbles be varied. It will be seen that the end marble moves farther away as the number is decreased; affording a good illustration that the force increases inversely as the length of the conducting line. Let now a sheet of paper, or a book, be placed perpendicularly for the end marble to strike against, and the marbles arranged in any number of lines—say three. If the three lines are impelled forward by the same motive power—a pencil held so as to strike the three lines at one time—the three end marbles will be impelled forward to the paper or book. Suppose that it were possible to register this action on the paper as three indentations, each of the same value, made in one second of time, it is plain we should have to impel one line three times—or once with three times the force—to produce the same value of indentation, and three times as fast to obtain three indentations in one second. The first result answers to electrical *quantity*, and the latter to electrical *tension*. We also see that with the greatest *quantity* the greatest amount of *work* is done, the resistance to be overcome being the same. Quantity, then, varies with the area affected; tension, with the number of times force is transmitted in a given time.

Having obtained some idea of the action of an atom when subjected to force, we have next to consider the direction of our force. If we consider electricity as a force, we must consider the normal atomic state to be that of comparative rest. Regarding an atom as a point in a line of force, the force tending towards that atom will be positive or negative to the force tending from the atom; positive and negative being used in the mathematical sense as referring to opposite directions. Electricians have termed that the positive current which flows from the copper pole to the zinc pole, or, inside the battery, from the zinc plate to the copper plate. If the reader will make the following simple experiment, he will see that the positive current is the only visible current in a closed galvanic circuit. Take a battery, and connect a piece of wire one end to each pole; sever the wire at any point, and apply the two ends to the tongue. On the side touched by the wire attached to the copper pole a sharp pricking sensation will be felt, *and on that side only.* Insert a galvanometer between the severed ends, and mark the direction of the index. Join up the severed wires, and insert the galvanometer in any other part of the circuit, the index will still point in the same direction, proving that there is but one current—that from the positive, or copper, pole. It would seem, then, that when electrical force is developed by chemical decomposition, the normal state of rest is destroyed, and force is imparted to the particles of the collecting plate, and thence to line.

There is ground, then, for the supposition that the current flows from the seat of action in one direction only. In further proof, Faraday's experiment with a silver-copper couple may here be quoted. Let two plates, one of silver, the other of copper, be placed in a vessel containing sulphuret of potassium. The needle at first deflects in a direction which shows that the copper is the positive element of the pair; it then gradually returns to its first position, and again deflects in the opposite direction, showing that the silver is now the positive element. After some time it returns, and again deflects in the opposite direction, and goes on thus changing. If the plates be examined during these changes, it is observed that sulphuret of silver is formed when the silver plate is positive, and sulphuret of

copper when the copper plate is positive. Nowhere is there any indication of more than one current. What reason, then, is there to suppose electricity a dual force?—in a closed galvanic circuit we have seen that there is but one force exerted in one direction. The only phenomenon that can be supposed to give rise to the idea that two forces are set free occurs when earth is made to complete the circuit. The battery then appears to draw up a current from earth to zinc—note that the direction is still the same—as well as send a current from copper to earth. Before we suppose another force to account for this flow, let us see if it could not be produced by the already existing force. Imagine that the wire is a tube of water and that, at the point indicated by the battery, a force is applied which imparts motion to part of the water on the tube. We know that the rest of the water will flow in the same direction. To return to our conducting wire: electrical force has been, and is being generated, the atoms in one part of the circuit are impelled forward to the limit of their space, and in their rear, so to speak, a kind of vacuum has been formed, having a tendency to increase, which the atoms in the other portion of the conductor endeavor to fill up, and, in the endeavor, are set in motion.

If this theory be true, it has the advantage in its favor that it does away with the complication of currents so difficult to the tyro in electrical science. Above all should we remember the aphorism, *Natura simplex est.*

Perhaps the greatest phenomenon of electricity is that it both produces and is produced by magnetism. Let us, then, define electricity to be, *a force capable of generating, and being generated by, magnetism.* In a short time, the writer hopes to submit to his readers the application of this definition and of Ampère's beautiful, because practicable, theory to the phenomena of static electrical force, and induction.

PRINCIPLES OF BRIDGE CONSTRUCTION.

From "The Engineer."

Notwithstanding the variety of forms which may be bestowed upon bridges, with all due regard to scientific designing and correct practical construction and the different principles embodied in each particular example, there are but two which can be considered to bear out the signification of the term in a pure and simple sense. They are the arch and the suspension principle. All other forms are either combinations or modifications of these in their outward shape or character of internal strain. The reason that the arch and suspension principles constitute alone perfect types of bridge construction is owing to the fact that they alone are acted upon by one description of strain, provided always that the conditions of theory are faithfully carried out in practice. There is a close analogy existing between the arch and suspension principles—in the difference between their relative shapes, or rather position, and in the difference between the nature of the strain exerted upon them under similar circumstances. The form of the one, and the character of the strain produced upon it, are exactly the inverse or opposite of those distinguishing the other, although the amount of each strain is identical. Obviously, for an entire structure, or any of its component parts, to be strained throughout by any single description of strain, is the most economical arrangement that can be devised. As the nature of the strain—whether tensile or compressive—varies with the principle adopted, the selection of one or the other, theoretically considered, will depend upon the limits of the relative resistances to the strains in question of the material of which the bridge is to be built. Practically, there are considerations which do not allow the dictates of theory to be followed universally in these instances. If we imagine an arch bridge to consist of a single voussoir or ring and a suspension of a single cord or chain, the subject of form and strain is reduced to its narrowest possible compass. In the comparisons of the strains upon these types of bridges—whatever may be their actual contours—they are assumed not to differ sensibly from an arc of a circle. It might be urged

that the arch principle may be simplified by imagining the whole arch to be replaced by a couple of rafters or beams forming the chord lines of the half arches respectively and meeting at the centre. But a moment's reflection will point out that this substitution violates at once the simplicity of the system. A transverse strain is induced on the rafter, in addition to the thrust which results from the portion of the arch principle which enters into the design. A practical example of this arrangement is to be seen in the case of a roof of tolerably large span, in which no ties or secondary trusses, for some reason or other, can be introduced. Each rafter is thus a beam or girder sufficiently deep and strong to carry its own load. Its upper and lower flanges will undergo strains of opposite character, and their calculation, and that of those upon the web, will be determined on the assumption that the design is simply that of an inclined girder.

If we take the analogous arrangement in a suspension bridge, and suppose a couple of tie rods extending from the centre of the span to each tower, the original tensile strain upon the curved chain becomes complicated at once by the inevitable "sagging" of the straight ones. Long unsupported tie rods cannot be used in practice any more than unstiffened struts of similar dimensions. The range of the former very much exceeds that of the latter, owing to the different conditions of equilibrium which are produced in them by the action of their respective strains. If a strut be deflected from its normal position in which its longitudinal axis is in a straight line, the strain induced upon it tends to deflect it still further from that position. But if a tie be placed in similar circumstances, the strain upon it will have a tendency to restore it to its original state of stable equilibrium. Until ties become of considerable length—as occurs in roof trusses, and in those examples of suspension bridges which are designed with straight rods—there is no necessity for stiffening or supporting them. It will be evident, from these considerations, that any attempt, however simple, to alter or modify the strict principle of the arch or suspension type of construction, leads to a direct complication both of parts and strains. The integrity of the two systems is immediately destroyed, a variety of elements being introduced which are completely foreign to the designs, abstractedly regarded.

From these two principles have arisen the numerous combinations that constitute the present practice of bridge-building. All of these differ from the primitive types, in being acted upon by strains of tension and compression, either separately or conjointly. Of the compound forms which embody the principle of the arch in their construction there are two, namely, the braced arch and the bow-string girder. The former of these has been used in but a very few instances, although it is, economically, a sound structure, especially for the employment of cast-iron, as the arch itself, and the horizontal or upper member, are both in compression. A distinction must be made between a braced iron arch and an arched rib, in which the whole strain is taken by the rib. The new bridge at Blackfriars is an example of the latter type. It is true that the spandrels consist of a simple truss of bars, but they serve merely to transmit the vertical pressure to the rib, and do not act as bracing in the sense it is understood to imply when applied to braced girders of any description. There is, practically, no strain upon the horizontal member of an arched rib. It is nothing more than a stringer, and although it is absolutely necessary to the bridge, both as a stiffener and to form a support for the roadway, yet the real resistance is supplied by the rib underneath. The heavy spandrels, the stringer, and the quantity of cross bracing that must be introduced between each separate rib of a structure similar to that recently erected at Blackfriars, cause a bridge composed of wrought iron arched ribs to be anything but an economical specimen of engineering. Another instance of the kind is the Victoria Bridge, carrying the London, Chatham, and Dover Railway and other lines over the Thames at Pimlico. On the other hand, in the braced arch the horizontal upper member does its own share of duty, and the bracing acts according to the correct signification of the term. It is, in fact, a web just as in an ordinary lattice girder, and undergoes strains of compression, or tension, or of both contemporaneously, as the load is partial or uniform, statical or dy-

namical. The other principal modification of the arch form is the bowstring girder, which is exceedingly well adapted for bridges of large span. In this respect it is quite equal, economically considered, and possibly superior to the horizontal lattice, although for limited span the latter is preferable. The bowstring is the arch with the substitution of a horizontal tie for the lateral resistance of the abutments, and the addition of bracing between the bow and the tie or string. The theoretical curve for the bow for a mixed load lies between the parabola and the ellipse, but in practice an arc of a circle is the contour adhered to.

The chief reason that renders the bowstring girder an economical form to adopt in large bridges is, that with a uniform load the strains upon the bracing or web are all of a tensile character. It will be suggested here that so long as the moving or maximum load is considerable, this is no argument in favor of the system, as the bars in the web must be made strong enough to withstand the maximum compressive strains to which they can be exposed. This is just the point we are coming to, and it is here that the length of the span becomes a part of the question. The effect of any moving load upon a bridge, supposing that effect to consist of two components, weight and impact, or, in other words, of a statical and dynamical component, is proportional to the ratio existing between the insistent weight of the structure itself and the moving load. It is the old story of a man lying down with an anvil on his chest, and another man striking it with a hammer, which of course bore a very small proportion in point of absolute weight to the anvil. By similar reasoning, when the moving load bears a small proportion to the dead weight of the bridge, its impactive or dynamical component may be very nearly if not quite neglected, since the moving load per unit of length is a constant, while the weight of the bridge per same unit increases rapidly with an increase in the size of the span ; the limit is not far distant when the effect of the impact may be omitted in the calculation. The moving load may thus be considered as a simple addition to the statical load, and the strains calculated accordingly. The bars will be subjected to compressive strains by a partial distribution of the load, but the proportions that have to be given to them by the exigencies of construction will frequently render them more than strong enough to support these without requiring counterbracing. So far as the bracing is concerned, the uniformly distributed load acts in direct opposite to the partially distributed moving load, and it is therefore readily perceived that in large bridges the size of the span may be reached, where the tensile strains due to the one completely nullify those of compression due to the other. While the bracing is thus relieved of a great portion of the strain which falls to the lot of its representative in the girder with parallel flanges, it must not be supposed that it is not resisted by some portion of the structure. It really falls upon the bow or upper flange, but from the shape of this member it is an easy and economical task to stiffen it against compressive strains compared with a long diagonal bar.

Returning to the suspension principle, the modifications of it have not been endowed with the success that has attended those of the other primitive type. Innumerable attempts have been been made by engineers to construct a suspension bridge, simple or compound, which shall be available for railway traffic, but as yet they have all been failures, and in our opinion, always will. We do not mean to assert that it is not possible to build an iron suspension of a very complicated character, which will allow a train to pass over it at the rate of fifty or sixty miles per hour. But we do assert that to do this would cost infinitely more than to erect the bridge upon another and a more secure principle. The difficulty of imparting to a suspension bridge the requisite degree of rigidity to permit of the passage of heavy loads at a great velocity, appears insurmountable. We have not space to mention the many different examples of this form, one of the most recent of which is the so-called cantilever bridges. These are nothing more than a spurious combination of a semi-suspension bridge and continuous girder, and are things to be avoided. They include all the disadvantages of both systems without any of their advantages. Many may be inclined to consider that the horizontal girder, or girder with parallel flanges, has a just claim to a title of its own as a primitive type of construction, as it is not

derivable in form or theory from either of the two which have just been discussed. In this sense, perhaps, it might; but its liability to strains of a double character debar it from that privilege according to the rules already laid down. In whatever particular shape it may appear, whether as a tubular, box, plate, Warren, lattice, trellis, or trough girder, its flanges are both subjected to strains of a different nature, and its sides or web is placed in a similar position. Of these, the tubular may be regarded as obsolete. We shall never build, or at least we ought never to build, another Britannia Bridge. They are costly blunders. The same may be said of the box form, which is only the double plate upon a scale so small that it is impossible ever to examine the girder when it is once riveted up. The "Warren" has exploded for any but limited spans, and would never have enjoyed the share of favor it has, but for the circumstance that it admits of the web being connected to the flanges by pins instead of rivets, and thus offers facilities for erection in localities where skilled labor is scarce and expensive. Regarding the trellis in the light of a burlesque upon the scientifically constructed lattice, we find the latter form and the plate to be the sole representatives of the horizontal or parallel system. There are no varieties of the plate principle, except that the web may be either double or single. But there are many varieties of the lattice girder, in consequence of the different arrangements that may be made with the bracing. Some of these are both unscientific and uneconomical. The web is comparatively the important point in the lattice girder, although the flanges must receive their proper share of skilful treatment as well. An investigation of the merits of the different systems of bracing will form a subject for a future article.

EXTRACTING THE PRECIOUS METALS WITHOUT QUICKSILVER.

From "The Mining Journal."

The great and apparently unavoidable loss of mercury in the extraction of gold and silver from their ores must cause considerable interest to be felt by all engaged in mining for those metals in processes which render the use of quicksilver unnecessary, more especially when, as in the case of the process to which most prominence is given in the volume* just completed by Mr. G. Kustel, M. E., whose works on the metallurgy of the precious metals are already favorably known among practical men, simplicity and economy are combined. The chief aim of the work is to explain the leaching, solving, and precipitation process for silver ores now successfully practiced in Sonora, Mexico, where it has been lately introduced by Mr. Ottocar Hofman; but, to enable those relying upon the book to insure success, he devotes three-fourths of the volume to the consideration of preliminary processes, upon the careful carrying out of which much, of course, depends. Referring to roasting, he observes that, as it is regulated by the peculiarity of the ore, and by subsequent treatment, it is impossible to give any one way which will be suitable in every case. The descriptions of the roasting processes are followed by accounts of the lixiviation process, and of the gold extraction processes, so that a complete hand-book for practical men is thus supplied.

Ores may be classified, Mr. Kustel observes according to the metal the extraction of which is principally remunerative, as silver ores, lead ores, copper ores; according to the metallurgical treatment, as roasting ores, smelting ores, amalgamating ores; according to the predominant gangue, as calcareous ores, quartzose, or ochrey ores; or according to the predominant metallic mineral, as sulphuret ores, chloride ores, carbonates, etc.; and he then gives brief descriptions of the more important silver ores, the difference between real silver ores and argentiferous, and of some of the more important combinations to be met with. Sulphur, he says, is the most formidable obstacle to the metallurgist, in extracting metals from their respective ores. Desulphurization has been a subject of most diligent and numerous exper-

* "Roasting of Gold and Silver Ores, and the Extraction of their Respective Metals, without Quicksilver." By G. KUSTEL. San Francisco, California: Dewey & Co. "Scientific Press" office.

iments. The oldest method is the application of heat, which is still in use, notwithstanding the many attempts in modern times to dispense entirely with fire, or to modify its application, so as perform the process more perfectly, and in a shorter time. The desulphurization of ores is effected by heating, with free admission of air. This is the common way of roasting, and the most important, and is effected either in kilns, heaps, etc., or in reverberatory furnaces; by heating with exclusion of air, only the sulphides of gold and platinum are decomposed perfectly by this method; by superheated steam, and by heating with materials for which the sulphur has a greater affinity. The general effect of roasting is that the metals are oxidized. Only gold and silver are transformed into a metallic condition; and of the silver, moreover, a large percentage is always found as a sulphate, even when the roasting is well performed. The most powerful agent of reduction is carbon (charcoal, coke, etc.,) and carbonic oxide. Metallic oxides in solution are reduced and precipitated in a metallic condition by other metals, or by the aid of electro-galvanic action. Although by mere desulphurization the silver is, to a great extent, converted into a metallic state, this is not always the most suitable condition, except for smelting. It would seem as if metallic silver should amalgamate more easily than if combined with another substance, yet this is not the case. The silver, after roasting, is generally coated with the oxides of volatile base metals, which prevent its ready amalgamation. A momentary contact in a muddy pulp is not always successful. The chloride of silver, however, goes into solution, and unites easily with the quicksilver. Hence in most instances it is necessary to adopt a chloridizing roasting; for this chlorine must be brought in immediate contact with the ore particles. The cheapest material evolving chlorine is salt, from which the chlorine is separated by substituting a substance with a stronger affinity for sodium. In practice, sulphuric acid is used to convert the chloride into sulphate of soda, and thus set the chlorine free. The two principal methods of chloridizing are by roasting the ore with salt in a furnace, and by passing cold chlorine gas through the roasted ore. The silver is easily obtained from the chlorine by melting it with alkalies; the chlorine unites with the alkaline metal, and the silver separates on the bottom of the crucible.

In the chapter treating of the roasting of ores it is explained that in order to chloridize the ore an addition of common salt is indispensable. The salt furnishes chlorine for that purpose and is decomposed by sulphuric acid. The sulphuric acid is created by the decomposition of sulphurets present in the ore. It follows that if silver ore is to be roasted successfully with salt, there must be a certain percentage of sulphurets in it, otherwise no sulphuric acid can be obtained, and consequently, no chlorination, or at least only a very imperfect one, can be effected. In Nevada and Idaho the ore only contains from 6 to 10 per cent. of sulphurets, yet gives a good result. As no pyrites are within reach, the want of sulphuric acid must, when necessary, be made up by the use of some other substance, such as green vitriol or copperas. As to the amount of salt to be used, and when, Mr. Kustel states that ores containing from 80 to 100 oz. of silver to the ton should be mixed with 10 per cent. of salt. Rich ore is often roasted with 20 per cent. of salt. If all the chlorine of the salt could be transferred to the silver, an insignificant amount of salt only would be required for ores containing 100 oz. of silver—not more than $3\frac{1}{2}$ lbs. to the ton; but, in consequence of the different way in which the chlorine decomposes and unites with base metals and gases, the escape of chlorine from the surface of the ore without coming in contact with the silver, etc., a great deal more of the salt must be applied. Permanent stirring is not essential, and Mr. Kustel remarks that a good chloridizing roasting should give over 90 per cent. of the silver converted into chloride of silver, and show as little as possible of base metal chlorides, which are formed under the action of chlorine and hydrochloric acid. When endeavoring to expel the base metals by heat, the loss of silver in presence of much antimony, lead, and copper, should be investigated very carefully. Under certain circumstances it is not uncommon to find a loss of even 50 per cent. of silver if the chloridizing roasting is carried on at a high heat for a great length of time. The formation of base metal chlorides can be avoided by a proper but more expensive roasting. It requires, first,

an oxidizing roasting with the application of steam. This roasting must continue until all the metals are desulphurized and converted into oxides. When this is accomplished, salt and green vitriol are added, and the roasting continued until all the silver is chloridized. There is also a very good way of getting out a great deal of the base chlorides of the ore before the silver is amalgamated or extracted by leaching the ore with hot water.

The importance of a knowledge of the condition in which the metals exist after roasting, is very great to the practical man. Mr. Kustel, therefore, considers it very fully; and with reference to oxidizing roasting, he states that its purpose is either to expel volatile substances which are combined with the metals, as sulphur or arsenic, or to expel volatile metals, which are considered obnoxious to the further treatment of silver ores (as antimony, lead, zinc, etc.). The oxygen has a large share in this transaction, and combines with the volatile substances as well as with the metals. After describing the leading principles of the roasting processes, Mr. Kustel refers, with diagrams and details, to the several furnaces in which the roasting is effected, and then explains the object of leaching. The roasted ore contains chloride of silver, which does not dissolve in water, but generally there are also base chlorides in it, as the chlorides of copper, zinc, lead, iron, antimony, etc., which are soluble. It is the purpose of the first leaching to extract these base metals by means of hot water. The ore is introduced into a square box of pine wood, the planks being $1\frac{1}{2}$ to 2 in. thick. The boxes must be made as water-tight as possible, and provided with a filter at the bottom; in these the base chlorides, soluble in water, are first thoroughly washed out, after which a solution of hyposulphite of lime is led into the tank to dissolve the chloride of silver. The liquid of the second leaching is conveyed through a trough or india-rubber hose to the precipitating tank, of which three or four are employed. The black precipitate of sulphide of silver is conveyed directly into filters made of canvas, either in the shape of pointed bags or otherwise. Mr. O. Hofmann, in need of sulphur for the production of sulphide of calcium, calcined the dried silver in iron retorts, and thus obtained a large proportion of sulphur as a fine sublimate; after this is removed the calcination can be finished with access of air.

But perhaps the most important process described in the book is that of Kustel and Hofmann, by which the roasted ores are so treated that the copper, gold, and silver can be obtained separately. The ore is moistened and then treated with chlorine gas, obtained from a generator of simple construction. The vessel is uncovered, and for a charge of 3 tons of roasted ore the ingredients introduced are—pulverized peroxide of manganese, 30 lbs.; common salt, 30 or 40 lbs., according to quality; sulphuric acid of 66 deg., 75 lbs.; and water, 45 lbs. Salt, manganese and water are introduced first, the generator covered, and the hydraulic joints made tight. The sulphuric acid is then charged through a siphon funnel in small amounts —20 to 25 lbs. are sufficient to evolve the chlorine and the required heat. When the evolution of chlorine becomes weaker 20 lbs. more of acid are administered, and after some time the rest of the 75 lbs. It will be necessary now to build a fire beneath the generator, which is placed on tiles, that the heat may not injure the leaden bottom, which is made of 16 lbs. sheet lead, while the sides are of 8 lbs. The chlorine is washed before it reaches the ore, through the whole mass of which the chlorine passes. As soon as the ore box is filled with chlorine, the outlet is closed and the fire withdrawn. In this condition the ore is left for 12 or 15 hours. The gas is then removed into another ore box, hot water is introduced into the first-named box, and the leach run into the precipitating box, where the gold is thrown down in a metallic state by sulphate of iron. The extraction of gold without the use of quicksilver is limited mostly to those ores in which the gold is not free in a metallic condition, but combined with sulphur or arsenic in the respective pyrites.

Although the book contains less than 150 pages, it will afford all the information likely to be required upon the subject and the illustrations of furnaces, implements, and working apparatus are excellent. It gives a condensation of most that has already been published, either in German or English, with reference to the extraction of the precious metals, and contains much that is new in the way of descriptions of inventions to which the

experience gained in the extensive mining operations carried on in the Pacific States have given rise. The merit of the work is beyond question, and as it is certainly as cheap a half guinea's worth as could be purchased by those for whom it was intended, the prediction of the author—that its chances of doing much good are far better than the probabilities of its repaying its author and publishers—is one which happily is not likely to prove true; it will doubtless find an ample number of patrons, both in the Old World and in the New.

THE TREATMENT OF AURIFEROUS QUARTZ.

From "Engineering."

The means adopted for the reduction of auriferous quartz, and the extraction of gold from it, in Victoria, have, it may be justly inferred, been brought to a state of great perfection, when it is remembered with how small a percentage of gold the mines of the Black Hill Company, described last week, are made profitable. The reduction of quartz is a comparatively recent industry, commenced long after the easier labor of surface mining had been established, and at first not only were the means employed crude and primitive, but the processes were very wasteful, and only such reefs were selected for reduction as showed the existence of gold in liberal proportions, such veins only as contained 4 or 5 oz. of gold as a minimum being considered worth working. In those early days the quartz, after it had been quarried, was broken up under the hammer, and this operation was succeeded by the slow and tedious process of reducing the stone, in a mortar and pestle, after which the triturated mass was subjected to a washing similar to that by which the miner in alluvial districts obtained the gold by pan-washing. Reducing mills, shaped after the fashion of coffee mills, were used after the mortar and pestle process had been abandoned, but the first favorable results were obtained with the jigger, a species of rude stamp, the head of which was made of iron fastened to a stem of timber, which was attached to the bough of a tree; the head of the stamp was placed about a foot above the ground, and the elasticity of the bough to which the stem was attached, facilitated the operations of the miner. Of the same class of apparatus was the dolly, a stamp fastened also to a timber stem, and placed horizontally across a vertical post, made with a seat at the top to receive it; the end of the stem opposite the stamp was weighted, and the stamp itself struck upon an anvil placed below. Rude as these contrivances were, good results were nevertheless obtained from them, and they held their own for some time until the Budan stamps were introduced. These consisted of a series of wooden stamps, shod with iron, working in combination with heavy balls, free to move in the amalgamating basin. This machine worked satisfactorily, but it was liable to disarrangement; it required frequent repairs, and the small quantity of quartz it was capable of reducing limited its application to the richer stones, and rendered it unsuitable for meeting the increased demand for reducing apparatus, which the stimulus that had been given to reef mining had received. Invention was soon busily at work, and rapidly one improvement succeeded another; stamping mills of a more effective character were erected by the different companies, until, at the present time, plant sufficiently perfect to accomplish the work required by poor associations, such as the Black Hill Company, has been produced. A few figures will show how great the advance has been in the machinery designed and erected for gold extraction. Thus, at the beginning, the cost of reduction reached from £10 to £14 per ton; four years later it had been reduced from £5 to £8; later again the prices were reduced to 10s. a ton, and we have already seen what can be done with effective plant at the present time. So that, while in the early times only such quartz as showed a rich proportion of gold was worth dealing with, while even those, sometimes deceptive in their quality, failed in the end to repay the cost of reduction, it was found profitable subsequently to work down 3 oz. stuff, then

a quartz yielding 1 oz. per ton, and now stone containing but 2½ dwt. Of course, even at the present time, locality and facilities for working regulate to a considerable extent the minimum percentage it is profitable to work. Two pennyweights and a half, which pay at Black Hill, are refused at Bendigo, where 3 or 4 dwt. quartz are only just profitable, and at Inglewood 1 oz. per ton may be considered the lowest average. It is, however, doubtless only a question of time, for still further improvements to be made in the reducing plant, and the difficulties that now present themselves in different localities to be removed. Then the wide extent of reef already known as gold-bearing, and others which have yet to be discovered, will afford an inexhaustible field to the labors of the miner.

The actual process of reduction and extraction varies almost in every mill, and while each quartz crusher regards his own system as the best, the good results that are obtained by varying means may partly be owing to the familiarity which each miner has of his own method. At the Atlas Company's mine, where the quartz contains percentages of pyrites, the stone is calcined, and then placed under the stamps. The reduced quartz is then passed over the ripple board tables and copper plates into Chilian basins, where the amalgamation is completed. The ripple tables consist of an inclined plane, and from 8 ft. to 14 ft. long, with grooves cut in them at short distances apart, and filled with quicksilver. All the quartz after it has been crushed, passes over these tables, at the lower ends of which are fastened the copper plates, coated with quicksilver, to catch the fine gold from the pulverized quartz. The good results obtained by the Atlas Company were due principally to the use of Chilian amalgamating basins. In the Concord Works, however, results nearly as good were obtained by blanket tables, in addition to the ripples and copper plates. These are inclined planes placed beyond the copper plates, and covered with baize, and they catch the minute particles of gold as the quartz passes over them. The Parker Reef Company employ, besides the ripples and plates, amalgamating barrels. These are mounted on a shaft passed through the longer axis, and they are charged through a square hole in the side, with the material, after it has passed over the plates, mixed with quicksilver. The contents are brought into intimate contact by the continuous revolution of the barrel, and a fresh charge is added every 48 hours. At the mine belonging to the Union Company, Tyrolean mills have been introduced. They are a modification of the Chilian basins, and despite the expenses attending their erection, the whole cost is shown to be recovered by a year's working, owing to the large amount of gold sand, which would otherwise have passed off in the tailings. Other experience has decided in favor of blanket tables in preference to the ripple tables and plate. Thus the Bee Hive Company are using blanketing only. Twenty-four feet of drugget are employed for each set of stamps. They are stretched in three or four lengths, with an inclination of 1 in 16, each length being placed a little below the preceding one, so as to make a series of steps, and give a slight fall to the material as it passed down from the stamps. In this process the only quicksilver required is a little under the stamps. The top length of blanketing is changed every three hours to prevent an undue accumulation of *debris* upon it, the others are worked in six-hour shifts. The time, however, is variable, being regulated by the amount of crushed quartz delivered from the stamps, for as the gold is retained in its slow downward progress by the fibre of the drugget, all that is necessary is to prevent an undue quantity of mud accumulating upon the blanket, and prevent the surface from doing its work. When the druggeting is taken from the frames, the deposits are carefully removed and washed in separate barrels, each length having its own vessel. The washings are also kept separate, and placed each in its own revolving amalgamating vessel, where they are kept in motion of six or eight hours. The result of this process is to bring every atom of gold in contact with the mercury, and effectually to separate it. The greater proportion of the gold is, however, held in the stamping, but the first or highest blanket table yields a considerable quantity, the second length gives but a trifling return, and the third is scarcely worth operating upon, giving only about an ounce of amalgam a week. Experience would appear to decide in favor of this inexpensive

and simple process ; indeed, it was found that out of 5 tons of the tailings from the the stamp mills of the Bee Hive Company, only 8 dwt. of amalgam could be recovered by the costly and finished plant of the Atlas Company, which, as we have seen, is provided with the Chilian mills. Indeed the returns of six months' working by the Bee Hive Company, during which time they crushed 3413 tons of quartz with an average yield of 14 dwt. to the ton, compard most favorably with their previous working.

To see, however, the perfection of economical and effective working, we must turn to the mines of the Black Hill Company. Originally they employed copper plates in conjunction with ripple tables and blankets; but the plates have been for a long while abandoned, and the blanket tables are stretched below the ripples. A small quantity of mercury is placed about every 12 hours into the stamp boxes, and the ripple grooves are also filled with it. Of the gold obtained by this process 60 per cent. is retained in the stamp boxes, 30 per cent. is absorbed upon the ripple table, and 10 per cent is arrested upon the blanketing. At the Clunes workings, ripple tables of a peculiar form are employed. The grooves are wide and deep, the quantity of mercury required is large, and all the crushed material is forced through the quicksilver before it can pass off at the lower end of the table ; by this means the gold is readily separated, while the residue falling on to the blankets is robbed of the small remaining portion of the metal that has escaped the quicksilver. At the Marlborough mines, ripples, plates, and the Chilian mill are employed. A similar system prevails at another mine, where, in addition, shaking pans are used, in which the crushed quartz is placed with the mercury, and the contents are well agitated. At the Prince of Wales mine, Chilian mills instead of stamps are used for breaking up the quartz, and the amalgamation is effected by means of shaking tables and pans. This process gives very fair results, the mills being effective, though slow in their action. We might continue the list of different mines where practice differs almost to an indefinite extent, but we have described the leading methods in vogue. It is probable that different quartz requires different treatment. The richer ores it would appear can be crushed more economically by the Chilian mills, where slow action is adapted to such places as have only a comparatively small amount to be reduced. On the other hand, stamping mills are especially adapted to poorer stones, where a large quantity has to be dealt with, and the greater proportion of gold which escapes the boxes and passes on to the blankets can be recovered by the ordinary method. It has been found that the use of hot water in the reducing mills produces better results than cold. In such localities as give to hand a plentiful water supply there can be little doubt as to the advantage of the blanket system working in combination with the crushers. If, on the contrary, the quantity of water available be limited, then the substitution of ripple boxes with mercury for the blankets is imperative. The stamping boxes should be provided with loose bottoms, or an undue proportion of gold would be carried over on to the ripples and blankets. It is absolutely necessary that the quicksilver employed should be retorted at frequent intervals, as it will not retain more than a certain quantity, and if surcharged the gold passes over and is lost. Until recently it was considered that frequent retorting was unnecessary, filtration being considered sufficient, and considerable losses occurred from ignorance upon this point.

Despite, however, the excellent results arrived at, a considerable waste of gold does often occur, as is evidenced by analysis of the tailings, and invention has been, and is, busy at work, devising means for rescuing every atom of the precious metal. Successful as many of these plans have been upon a small scale, scarcely any of them have answered when put to the test of every-day work at a reducing mill. One system, however, which promises well, has been proposed and largely experimented upon with success. The principle is that of separation by gravitation. A series of four boxes, each of the form of an inverted pyramid, are arranged close to the batteries. The two first of these are of the same size, the third has a capacity equal to the two, and the fourth is double the size of the third. The whole of the stuff, as it flows off from the battery, passes into the first and second vessels, and the fall of the "sludge," from the battery

boxes into these vessels, keeps their contents in a constant motion, that helps to disengage the heavier particles of gold and quartz, and precipitate them to the bottom, where they fall through a pipe, and are passed out upon ripple boxes with deep grooves, through the quicksilver of which all the material is passed, upon the method we have already described. The stuff flowing off the ends of these ripple tables falls into the third and larger box, where a precipitation of the finer particles takes place; and this residue is led off to pass over a second set of ripples, and again to flow into the fourth box. In this are contained the finest atoms of gold, and these are arrested by silvered plates of copper, placed in the box at angles, so as to intercept the particles which are either floating on the surface, or slowly settling to the bottom. In addition to these means, blankets also could be added. It is evident that there are many advantageous features in this plan. It is inexpensive and self-acting, whilst the results obtained from it have been remarkably good.

The presence of pyrites in gold quartz is a fruitful cause of waste, and calcination of the stone has been tried to disengage them, as well as to soften the quartz and make it easier for crushing, but without much success. At many of the workings a great and constant loss ensues from this cause, and but little has been hitherto done to effect the saving. Nay, more, many reefs profitably rich in gold, are yet too full of pyrites to admit of their being worked, while others worked at certain levels, have to be abandoned because the pyrites increase rapidly at low levels. It would, however, seem probable that a means could be adopted of separating the pyrites after the ore was crushed, mechanically and by gravitation. And indeed the apparatus just described effects the object partially, but a perfect means yet remains to be introduced. It need scarcely be said that when this shall be done, the prospect of gold winners from the quartz will vastly increase, while the enormous accumulation of tailings at the different mines will yield a handsome profit upon the labor and outlay of reworking them.

VEGETABLE TEXTILE FIBRES.

Translated from "Comptes Rendus."

Vétillart introduced before the Academy at Paris a paper concerning the differences of the most important textile fibres, of which the following is an abstract as given by Chevreul :

The treatise considers the six most important vegetable fibres : flax, hemp, cotton, jute (*corchorus capsicalis*), Chinese grass (*urtica utilis*), and New Zealand flax (*Phormium tenax*).

The differences are determined by means of microscopical observations of the colors imparted to the several fibres by iodine, in solution of water or sulphuric acid diluted with glycerine. The fibre must be examined longitudinally and transversely. It must be prepared in different ways, dependent upon its condition, whether raw, dressed, or colored. The raw fibre is soaked for half an hour in a weak lye of carbonate of soda, and is then washed ; the dressed is treated with boiling water distilled or slightly alkaline ; the colored is dyed as completely as possible.

A few fibres separated from a bundle 6 @ 8 centim. long are placed upon the object slide of a microscope, are saturated with glycerine or a solution of chloride of calcium to make them transparent, and are covered with a glass plate.

A solution is made with 1 part iodide of potassium in 100 parts of water ; a large drop of this solution is placed upon an object slide, a few fibres are put in it ; after a few minutes the excess of fluid is removed with blotting paper, and a glass plate is put over it ; a few drops of sulphuric acid diluted with water or pure glycerine are applied at the side of the glass cover, and the excess of acid on the other side is removed by blotting paper. All the excess of iodine must be removed in this way.

To observe a transverse section of the fibre a bundle about 3 centr. long of the size of a goose quill is tied around the middle with a thread ; first one end, then the other, is dipped in a solution of lime and glycerine until the lime is uniformly

distributed throughout, the parallelism of fibres being carefully preserved. When the bundle is dry (in about 12 hrs.) it is held in a pair of pincers and cut across by a razor into slices as thin as possible, which are put under the microscope.

The following are the results of observations on fibres treated in this manner.

Fibre of flax which seems single to the naked eye is in fact a bundle formed of united fibres. The elementary fibres can be easily separated by means of a needle. They are from 1 @ 6 centr. long; are uniformly thick; are pointed at the ends, and contain a very minute canal. They are smooth; only those growing from the lower part of the plant being flat and ribbed. Iodine and sulphuric acid dye them blue, sometimes a wine-red; the canal is dyed red. Polygons are observed on the transverse section, which easily separate. These are dyed blue, but yellow at the centre. This slight adherence of fibres, the uniformity of their diameters, and the smoothness of their surface are the reasons that they can be spun into threads containing numerous fibres.

Fibres of hemp are crowded close together, each being surrounded with a thin substance which iodine dyes yellow, not blue. They are about as long as the fibres of flax, but are thicker and rougher; their ends are thick and spatulate. These are dyed blue or greenish blue by iodine and sulphuric acid. Transverse sections of hemp differ from those of flax in the appearance of complexity and adhesion of fibres. Each fibre is colored yellow at the circumference, blue within.

Cotton fibres are always isolated, ribbon-like in the direction of their length, and folded in the middle. Their ends are broad; they contain a central canal, and are dyed blue by the iodine solution. The longest fibres are 25 @ 40, the shortest 10 @ 20 mill. long. In section they always appear isolated and rounded, kidney-shaped. Iodine dyes them blue with yellow spots.

The fibres of jute are closely adhesive, undulating at the circumference and hard to separate; they contain a wide empty canal of varying dimensions, and are flat and rounded at the ends; they are dyed light or dark yellow by the iodine solution. The transverse section presents a polygonal appearance like flax; but the central orifice is larger. The iodine gives a yellow color to the sections, and a dark yellow color to the boundaries of the polygons. Very white jute is dyed dirty blue or green. Moisture separates the fibres. Threads of jute cannot be knit together because they cross at too great an angle, hence its use is limited. They cannot be treated with lye.

The fibres of Chinese grass are isolated and are 5 @ 12 centr. long, while those of hemp seldom exceed 6 centr., are variable in thickness, appear to be ribbed obliquely, and dye blue in the solution. A canal within is often filled with a yellow granular matter which is itself a dyestuff. This wide canal is especially visible in section, presenting very irregular forms and angles.

New Zealand flax consists of the fibres of the leaves of *Phormiun tenax*. They are very fine and regular; 5 @ 12 mill. long, and easily separated by a needle. A uniform canal runs through their length. They generally taper at the end. They are colored yellow by iodine. The section is like that of jute; but the corners of the polygons are rounded. New Zealand flax, like jute, must be kept dry, and does not resist the action of lye.

Belgian Rails.—The exportation of rails from Belgium, which greatly increased last year, as compared with 1868, presented but a small farther advance in the first six months of 1870. Belgium exported, however, in the first six months of this year 19,566 tons of rails to Russia; to the Zollverein, 18,318 tons; to Turkey, 12,356 tons; to France, 4,109 tons; to Italy, 3,832 tons; to the United States, 2,999 tons; to Sweden, 1,700 tons; and to Spain, 1,657 tons.

Gas and water works are about to be established at Wellington, New Zealand. The pipes for the water works have already been shipped from England, and have possibly by this time been landed in New Zealand.

Recent experiments in different places show that an average of 44 per cent. of the rain-fall on a surface of country may be collected in basins or reservoirs.

APPLICATION OF SCIENCE TO INDUSTRY.

From "The Building News."

Dr. Lyon Playfair, in a lecture recently delivered before the Midland Institute of Birmingham, said: "When any tribe or nation can take from another the raw material, which the latter either does not use, or uses with less intelligence, the first nation must be under the guidance of science. The science may be undeveloped, dealing with qualities only and not with quantities, but science it must be; for it is impressing upon the material the conception derived from a cultured intelligence, and making these of a higher relative value than the mere local possession of the material itself. This is the great element of industrial competition in the world at the present time. Take the case of Great Britain in modern days. We have in large quantities, and in fortunate proximity, coal, iron, stone, and lime. We have copper, and tin, and zinc, in smaller proportion. As intelligence arose in this country, and initiatory science became evolved from industrial persuits, the inhabitants no longer sold their mineral wealth to distant nations, but manufactured it for themselves. As long as the growing intelligence of our inhabitants equalled or exceeded that possessed by any neighboring nation, our prosperity was secured; because, in addition to the science of the time, the raw material of industry was in our possession, and competition with us was an impossibility. And so it is with all nations. But the moment that any nation allows the intellectual element of production to fall below that of its neighbors, the local advantage no longer suffices for superiority. When commerce and science open up paths of rapid intercommunication throughout the world, the cost of transit of raw material is diminished, and the intellectual superiority of another nation far more than balances the possession of raw material. Roads, railways, ships, and steamboats, arising in the march of science, can spread raw material everywhere, and enable nations to test their relative intellectual powers applied to it. Let us take a case: Cotton being indigenous to Hindostan, calico was made at Calicut. Soon the intellectual culture of the Arabians exceeded that of the Hindoos. Calico was manufactured by them, and introduced into Spain, where it flourished. Then came the great national crime of Spain, in the beginning of the seventeenth century, when a million of the Moriscoes, who still possessed the experience in manufacturing industry, were suddenly expelled on account of their doubtful Christianity. With them, cotton, woolen, and silk manufactures were also ejected from Spain. The 15,000 looms of Seville were thus reduced to 300, and the 40,000 silk weavers of Toledo lost their subsistence as soon as the intelligence and skill of the Moors passed to Tunis. In process of time this country took up the cotton trade which Spain flung away, and made it our own by great mechanical inventions. Not, be it observed, by manual labor, but by the result of intelligence applied to machinery and locomotion. And look how much intellect now exceeds the value of the raw material as a factor in production. Cotton is grown in America, crosses the broad Atlantic as a bulky and expensive freight, is seized hold of by our mechanical science and manufacturing enterprise, crosses the Atlantic again as calico, pays a heavy import duty, and yet undersells the products of the mills at Lowell. When the great American people, through their rising colleges, and by a better understanding of the effects of restrictive tariffs, apply their intellectual powers in this direction, such relative superiority of manufacturing science will be impossible, in the presence of the raw material at the door of their mills. More strange still to see Switzerland, with no seaboard and no coal, bringing cotton from America, transporting it through the defiles of the mountains, then back again over land and sea, in the form of high-priced cotton goods, underselling America in her own markets. What enables such a country to do this? It is not cheapness of labor; it is intellectual or scientific superiority in relation to the manufacture which competes successfully against local advantages. Take another instance. Sweden has excellent iron, and we send for it to Birmingham, where you convert it into tools, axes, chisels, and hoes. You send these to America, though good iron ore

exists in that country. Well, some day the Americans find that by giving a different edge and temper to their axes, or a different form to their hoes, they can do their own work better; so they send to Sweden for the iron, and fashion it into their peculiar forms, and Birmingham does not send so many axes and hoes as formerly, but America actually sends over some to this country, to see whether we like their new forms better than our own. You see that the mere possession of the raw material confers but a small advantage on the country, and that the changes which are continually taking place are not regulated by it. The intellect, which has such a predominant value, receives its expression, at least to a large extent, by incessant efforts to convert the brute labor of a man into an intellectual superintendence of labor performed by a machine. This may be illustrated by any branch of industry taken at random. I see opposite my study window, as I write, a house in course of erection, and the labor of the builder will serve my purpose as well as any other.

An Irish hodman is carrying a quantity of bricks up a ladder, in order to supply material to the builder. The sight is familiar to us still, though not as much so as it was a few years since, because a change is passing over this form of labor. Let us study the reasons for the change. The Irish hodman is a human machine, unskilfully and expensively put into operation. He felt that himself, in his fine, confused way, when he wrote to his friend in Ireland, "Dear Pat, come over here and earn your money; there is nothing for you to do but to carry the bricks up a ladder, for there is a man at the top who takes them from you, and does all the work!" The man at the top is a skilled workman, more nearly fulfilling his human functions, for he is using intellect in his work. The hodman is a worker also, but only a user of his own brute force in a very unintelligent way. Every time that he ascends the ladder with his load of bricks, he is carrying his own weight in addition to that of the bricks; his force is thus wastefully expended. After many years his employer perceives this, and substitutes human labor first by that of a horse, then by that of a steam-engine. Now, when you pass a house in course of erection you will see a horse trotting over a prescribed course. It is pulling up a whole barrowful of bricks by a rope and pulley. The horse, tended by one man, is doing the work of seven or eight hodmen, and with much economy of money, inasmuch as the cost of the hay and oats, from which its power is derived, scarcely exceeds that of the beef, potatoes, and beer of a single hodman; while increased economy of labor is also attained, because the weight represented by the bodies of seven hodmen is not drawn up along with the bricks. Food, burned within the bodies of the men and the horse, is in both cases the source of power. Again, in large houses the horse disappears, and a small steam-engine draws up the bricks. Economy is again achieved, for the coal, which is the food of the engine, is less costly than the hay and oats required for evolution of force in the horse. A single man, using scientific knowledge in the guidance of the engine, is now doing the work of several horses or many men. Let us analyze the changes which pass over the forms of labor illustrated in this particular case. The first tendency is to substitute the brute force of a man by an intellectual superintendence of a cheaper form of force, either animal or physical, the aim being to obtain economy of production, either through economy of time or by the substitution of a cheaper form of force for human labor. In fact, economy of time generally follows the economical substitution of force. Savages have an utter disregard of time in the performance of labor. They will expend a month in sharpening a single arrow. Some of the rock crystal cylinders worn by chiefs for ornaments, are stated to take two men's lives to perforate. The Kamchadals, of North-eastern Asia, take three years to hollow out a canoe, and one year to scoop out the trough in which they cook food. As soon as a savage tribe employs fire, instead of implements made of stone or bone, to hollow out their canoes, they are using a natural power to economize time and brute human force, and are on the high road to civilization. In human progress it is always so, for it is a natural law that the sweat of the brow should be lessened by the conception of the brain. The economy produced by the substitution of cheaper for dearer forms of force is remarkable in all cases

where it is applied. The Prussians saw this very well when they wanted to make England declare coal as contraband of war in the present campaign, that it was representative of so many men added to the enemy; for three or four pounds of coal, even in the wasteful way in which it is used, are more than equal to a man's force. I recollect, some years since, reading an interesting address on this subject by Sir William Armstrong. When coal was first an object of commerce, it was transported on the backs of men from the pit's mouth to the sea-coast. A man, in this way, might carry a load of half a hundred weight; but after a time a pack-horse was substituted for the man, and carried about three hundred weight. As science progressed, the pack-horse was attached to the wheel-cart, into which its load was put, and it pulled down sixteen hundred weight. Then, as industry progressed, tram-roads were laid down between the pit and the coast, and the same horse, pulling a wagon, carried forty hundred weight. Finally came the great triumph of science, when coal was employed to pull itself. The smoking, snorting iron horse, fed with coal and water, drags along the railroad 200 tons. The conversion of coal into force, which produces this great result, is, in point of cost, scarcely greater than that of the human beast of burden, or the pack-horse originally used for a scant result. And yet our engines are so imperfect that they only use one-tenth and waste nine-tenths of the available force in coal! The importance of the transformation may be better understood if you view the force of coal as expressed in men's power; just as we do in speaking of an engine as having so many horse-power. If human force were alone used in this country, the sum of production must be limited by the number of inhabitants. In such a case the United Kingdom could not produce more than the products of the labor of its thirty millions of inhabitants of all ages. But the coal excavated annually in this country represents in actual attainable work almost exactly the sum of the force of the whole population of the globe, viewed as adults. So that the use of a natural force, in substitution of human power, augments vastly the productive resources of our small insular kingdom, and enables it not only to supply its own wants, but also to export to other countries its superfluity of production.

BRITAIN'S STRENGTH.

From "The Engineer."

While "all day long the noise of battle rolls" around us, it is impossible to divert our thoughts from the mighty conflict waged by the two greatest military powers of modern times. The years of tranquillity which followed Waterloo and preceded the International Exhibition of 1851, lulled civilized minds, and led men to believe that the approximate peace of 40 years could not be disturbed by angry passions, the operation of national jealousies, the desire for glory—save the mark!—or a manifested and active desire for national aggrandizement. The dream —'twas but a dream—was readily dispelled, is it necessary to say how? What of the "glorious six hundred?" What of Cawnpore and Lucknow? Swiftly and surely on the epoch of calm followed the period of storm; poor human nature asserted itself, as it will till time is no more, and slaughter and devastation, and the havoc of the dogs of war, slipped once again, racked and distracted Britain. What is the picture before us now? Two little months ago war on a great scale appeared to be impossible. Since last July the civilized world has been carried back; yesterday is a Pharsalia, to-morrow may be an Agincourt, the day after a Balaclava. In this matter of fighting, the world has made no progress since the days when a great teacher told us of the strong man who keeps his house till a stronger than he comes and takes from him all that he has. It is madness—worse, sheer downright idiocy—to believe for a moment that if we would be comfortable, if we would be nationally happy, if we would lie down in our beds in peace, we can be so and do so without being prepared for war. It is an old saying, that "it takes two to make a fight;" just so. But Britain is only one. If France or Prus-

sia had chosen to fall foul of us instead of a nearer neighbor, where would England's strength, riches, glory, or power be now? If we would be at peace we must be prepared for war. The speculations of the Peace Society, the doctrines of men who preach a universal millennium, vanish like chaff before the wind in moments like these. If we would be safe we must be strong. In what shall our strength consist?

All our contemporaries have made up their minds on this point. They can see nothing but great armies in the field and able commanders of soldiers. The power with the greatest army and the ablest commanders wins. "Let us," they sapiently cry, "have great armies and great commanders." In the want of those things lies our national weakness." Nothing is heard of but our weakness; we are feeble in every joint and muscle. This is a miserable wretch of a country, a ready prey for the spoiler; so, at least, the daily press tells us diurnally, and it suggests the remedy—more soldiers. more soldiers. Now, we have not the slightest hesitation in stating that journalists who inculcate such notions as these completely fail to understand in what our weakness and strength really consist. Instead of looking at principles they handle circumstances, coincidences, analogies, imaginations. Their susceptibilities carry them away; their pens are guided by the emotions of the heart, not by the sound reasoning of the head. Because this war is a war of armies, nothing is spoken of but armies. We would adventure large moneys on a wager that if this had been a war between naval powers—a war of ships—not a word would have been said about increasing our army. Every possible pressure would have been brought on the Government to augment our naval forces. Nay, more, although not a word is to be found in the columns of our daily contemporaries about strengthening our navy now, we are absolutely certain that a single naval engagement between France and Prussia of moderate dimensions would induce such a run on the navy as English journalism has never seen. Standing just a little way off from our contemporaries, and possessed of information which they are not expected to possess, let us consider for a moment in what, not Britain's weakness, but Britain's strength really consists.

The strength of Britain lies in four things—her insular position, her wealth, her navy, and the indomitable fighting obstinacy of her people. Of her wealth we shall not speak; of the stubborn courage of her sons we need not tell the story. To the influence exerted by her geographical position and her navy we shall confine our attention.

England, to be safe, must be able to do two things—keep off invaders, and protect her colonies and her commerce. No standing army, no militia, no volunteer force, which a small country like this could possibly sustain save at a ruinous cost, worse than war itself, could possibly prevent invasion and national destruction. The foot of an invader must never be planted on English soil. To secure this end it is absolutely essential that we should possess an overwhelming naval force. Six hundred men in a powerful iron-clad will do more for the defence of this country than six regiments of the line at their full strength. We must set a limit on the number of men told off for defence. Every second man in London cannot be a policeman; every man cannot be a soldier. As, then, our forces are numerically small, and must always be small, put them into ships, where the power of each individual is multiplied by ten. There are but two nations now existing likely to give us trouble, America and Prussia; it will be years before France contemplates invasion. What must that fleet be which can carry 100,000 men across even 20 miles of water and land them on a hostile shore in the face of even a small army? The only chance of success would lie in a plan like this: The enemy's transports would lie, say in Cherbourg, Havre, and one or two other towns on the French coast. The troops would be quietly put on board. Meanwhile, a fleet of iron-clads would sweep the Channel clear of English ships, and then guard the Straits of Dover on the one hand and the chops of the Channel on the other, so that no other fleet could enter. At the proper moment the transports would steam across and prepare to land troops on 2 or 3 unprotected places on the coast, while the iron-clads would close up on either side to cover the landing; under such circumstances we believe

a landing would be effected do what we could. If the Prussians attacked us their policy would be much the same. The German Ocean would be pretty well scoured by iron-clads, and our ships driven off. The transports would then throw their troops ashore under fire of heavy guns. All this is plain sailing, and looks very nice on paper; but even on paper it is obvious that the whole success of the invading army absolutely depends on the absence of English iron-clads at the time of invasion. Being present, the transports would be sunk, buried, and destroyed in an hour if they were unarmed. If iron-clads were used, it would be impossible for them at the same time to engage the shore, our iron-clads, and land troops in boats. The most helpless and unmanageable creature in existence is a soldier, especially a foreign soldier, in a boat. Probably sea-sick, certainly wretched after the passage, the invading army would be comparatively helpless. Pounded by light artillery and riflemen from the shore, without the power of firing a shot in return, troops so landed would simply be thrown away. But how would the case stand if our fleet were driven off boldly or kept engaged by a more powerful force? The enemy's guns would effectually silence any batteries we could bring to bear, just as the Confederates were silenced by the monitors at Fort Fisher, and the troops would be landed, and fed, and refreshed before they marched inland. It is all very well to talk about our fortifications, but no enemy would be fool enough to go near a fortification; he would pick out quiet spots, such as Sandgate or Herne Bay, Margate, Bournemouth, or Folkestone. Nothing we could do would prevent invasion if our ships were beaten. No invasion is possible so long as we have information enough of the enemy's movements, and ships and men enough to baffle and defeat the aims of these movements. It is to the augmentation of our fleet and their crews that we must look for national safety; for the avoidance of such a disaster as that which has befallen France. In England's fleet lies Britain's strength, and we are happy in the knowledge that no other nation in the world—thanks, we say with all honesty, to Mr. Reed—has a fleet so powerful, or—thanks to Woolwich—has so mighty an armament. But we have neither ships, men, nor guns enough to protect at once every portion of our coast and our commerce. On this point we may state that we believe it to be an entire fallacy to believe in any case that if we have ships enough to cover every probable point of attack on our own shores we have all we want. Nothing of the kind; our policy must be, not to watch our own shores, but the enemy's; we must do as Nelson did—never let a hostile fleet out of port without the certainty of a naval engagement. Our commerce cannot be injured, our colonies cannot be attacked by any European Power—except Russia marching on India—so long as we allow no hostile ships to get out. We ought to have ships enough not only to patrol the seas and pick up stragglers, but to watch every port of a foe where it is possible he could fit out a fleet. The mischief must be nipped in the bud or not at all.

We believe that this is comparatively a novel aspect in which to put our national position, but it is the only true statement of that position. Let us hope that we shall find sensible men, as soon as the first flush of the novelty of the present war has worn off, raising their voices and using means to induce Government to strengthen our navy. It is right and proper that our army should be augmented. It is essential that our volunteers should be supplied with breech-loaders. There is not a coast-guard station in the country where a battery should not be erected and one or two guns mounted. We have thousands of cast-iron guns lying at Woolwich which are useless against iron-clads, but properly handled, and used with grape or canister, would tell fearfully on the crews of boats attempting a landing. These little batteries disposed at close intervals would serve to train up a body of first-class gunners among us if they did nothing else. Remember that they are not wanted to operate against ships, but against boats packed as full as they could hold with troops. But neither a standing army, coast batteries, nor volunteer riflemen, can give us security. That for England lies in her great navy, and in that alone.

The 112th Asteroid was discovered recently by Prof. Peters, of Hamilton College. It is to be called Iphigenia.

A JOURNEY INTO SOME OF THE IRON-MAKING DISTRICTS OF THE CENTRAL PROVINCES OF INDIA.

From "The Mining Journal."

In several places in India I had frequently met with iron slags and furnace cinders, evidences of the past existence of native smelting works, and often had I felt and expressed a wish that I might some day fall in with the native iron smelters at their work, but it was not until a short time ago that this wish was realized.

Leaving Chanda by the road to Moohl one has to pass through about as dense a jungle as Indian traveller ever meets with—a jungle growing out of the soils and clays of coal-bearing sandstones, or at any rate of sandstones beneath which other sandstones bearing coal seams occur. These sandstones continue for more than 20 miles eastward of Chanda; and Mather and Platt's steam boring machine, worked by Mr. W. P. Mather, is now steaming away in the jungle, for the purpose of ascertaining particulars as to the occurrence of coal seams below.

Chanda is not only the name of an Indian town in this part of the great empire, it is also the name of a large district in the Central Provinces, and since the discovery of coal by the indefatigable Deputy-Commissioner, Major C. B. Lucie Smith, it is also the name of a coal field Westward from the town, and at a distance of about 15 minutes, a pit has been sunk to coal; at about 80 ft. deep a four-foot seam of good coal was passed through, and about 12 ft. below this a seam of upwards of 30 ft. in thickness has been penetrated. The Viceroy of India, Earl Mayo, descended this pit on March 1 last, and inaugurated Chanda coal mining by hewing a piece of coal from the large seam. His Excellency on returning to the surface graciously granted permission to name the pit "The Mayo Colliery," and a village near to the pit is to be henceforward known as Mayo Town. In referring to the coal and coal mining in this way, I have not made an unnecessay digression.

We started on our journey from Chanda to Moohl in an easterly course; Mr. Mather, disturbing the stillness of the jungle by his steam borer, was passed about three miles from Chanda, and the coal-bearing sandstones were left behind us at a distance of something over 20 miles. Associated with the coal measures sandstones, there are bands of highly ferruginous rock, from some of which I fancy the native smelters have at one time taken iron, as furnace slags are met with near them. I hope to have a variety of them assayed for the metal, and some of them analyzed with a view to their suitability as ores for reduction on a large scale. Here, too, as in many other parts of India, are the wonderful laterite beds, locally known as "mooruni." At Chanda itself, on the Moohl road from Chanda, and at the Mayo Colliery, to the west, these beds occur close to the surface; they vary in thickness from a few inches to many feet, and consist mainly of a coarse ferruginous gravel, which in Britain would doubtless be used as a source of iron. You will see from the map that our journey from Chanda is towards one of the great feeders of the River Godavery—the Weingunga; but some miles before coming to this we have left the coal field behind us, and are now in regions of metamorphic and gneissoze rock. Our route now, too, is more northerly than westerly. At the small village of Chicklee, on this, the western side of the Weingunga, the native iron smelting furnaces were for the first time seen; it was to me, as I have no doubt it would have been to most of the readers of the "Mining Journal," a sight of great interest, and curiosity. I had formed but a very imperfect notion of the mode of operation of iron smelting by Indians from what I had heard and read, and for the benefit of others who may have formed similar notions I shall make a description of the operation clear by a few illustrations. The simplicity of the mode is vastly amusing, and an old dusky son of Vulcan was very indignant at my inquiring if there was any other method employed for iron smelting than the one we were witnessing. His reply was, "What other way can there be?"

The furnaces are built of mud and stone, and their interior, or crucible, is repaired by mud and cow-dung after every "draw" of the metal. The inside of the furnace

is a truncated cone of about 14 in. in diameter at the base, and 4 in. at the top or truncation. The outside is from 5 to 6 ft. in height, has a base of about 3 ft. 6 in. in diameter, and slightly tapers towards the top. The blast is produced by 1 man working a pair of bellows, or by 2 men each working 1 large bellows. The small ones are simply goat-skin bags, made at one end to taper to a small burnt clay tuyere, and at the other provided with a pair of wooden lips, on which small straps are fixed for the operator's hand. In drawing the bellows out to fill with air, the lips are kept open; then they are suddenly closed, and a skin-full of air forced into the furnace. As the right-hand bellows is pressed inwards to discharge its load of air into the furnace, the lips of the left-hand one are opened, and drawn outwards to receive its load, and *vice versa*. Thus as the hand holding one skin closes up the lips and presses inwards, the hand holding the other opens the lips and draws outwards, and by this means a continued blast is produced. The operation, simple as it seems, requires considerable practice before it can be done with the rapidity required. The blast for all the native smithies and forges is produced by the same means, and often one sees the wife or daughter working the skin for their relative "the village blacksmith." The iron ore is broken up into very small pieces preparatory to its reduction in the furnace, and after the furnace has been well heated, the ore and the charcoal are mixed together, in proportion by measure of about 1 of the former to 5 of the latter, and then poured into the furnace from the top. After blowing for about twelve hours, the skins and the wooden stool on which they rest are removed, the tuyere holes closed up, and the furnace tapped just below the tuyere holes to let off the slag. The mud and small stone wall forming the side of the crucible under the tuyere holes, is then removed so as to make an opening of about 1 ft. in area, and the metal, which now looks like a lump of cinder, is withdrawn by large tongs, and hammered, as it is being rolled about on the sun-hardened earth. After this operation is completed the mass, weighing from 20 lbs. to 25 lbs., is cut nearly into 2 parts by a common native hatchet, so as to show the quantity of utilizable iron it is likely to yield, and then it is ready for the market, so far as the smelters are concerned. Occasionally, when the proportion of cinders to metal is large, the mass is re-heated in a rudely-made hearth, and rolled and hammered as before. In this state it is bought by blacksmiths in the vicinity of the furnaces and forged into small bars, 6 to 8 in. length, and fron $1\frac{1}{8}$ to 2 sq. in. in cross section, and then sold at local fairs and bazars to the village smiths for making agricultural implements, cart-wheel tyres, the small hatchets for wood chopping which one sees on the shoulder of every native "clodhopper," and various other things of minor demand, as nails, spikes, clasps, etc., used in native hut-building.

From what has been said, it will be seen that no flux is used. The ore used in this part of India, is a rich magnetic oxide, which on assay by the Government analysist in Bombay yields 68 per cent. of metallic iron, showing that there can only be from 4 to 5 per cent. of earthy matter to get rid of in the blast furnace. Goonjwye is the first place come to in journeying from Chanda, where iron ore is being mined by the native smelters. Here shallow lodes are being dug at the foot of a hill, and the ore obtained in small fragments under from 2 to 3 ft. of surface earthy debris, and extending over a range of several hundred feet from the hill, and along one side of it. In ascending the hill from this range, and until reaching the top, a height of about 50 ft., and up a slope of more than three times this distance, I found that every piece of stone one could possibly pick out of the thick jungle was a piece of highly magnetic iron ore. At the top of the hill the ore presents itself in huge blocks, lying in and on the edges of a natural quarry, one side of which consists of hard gneiss, and forms the hill flank opposite to the one, by which I ascended. From this quarry, or crater, one may reasonably surmise, have been forcibly expelled by volcanic blasting the fragments of ore now found at the base of the hill, and from which the native furnaces in the vicinity are supplied; and the wall of gneiss so well defined, and although seen for only a short distance owing to the jungle, indicates the presence of an iron ore lode.

I must here say a word or two about the interest one cannot help feeling in a spot like this, apart from geological or

mineralogical questions. Where the large blocks of ore and of gneiss are heterogeneously scattered, and Vulcan has himself mined or quarried on a scale far surpassing human efforts, an open space is formed, and is closely surrounded by trees, and these again filled in about their trunks with smaller jungle. It is to such places the native Koonbees and Gonds are drawn by sacred influences to perform their religious ceremonies, and at such places where, perforce, one feels as if in Nature's own cathedral. Here, for many a year, on the special annual feast day, must the native devotees have brought the image elephant, formed out of plastic clay and baked into hardness, and through this emblem of power worshipped the Deity, as many an image, perfect, and in various stages of decay, and the wreck of many more, are heaped together in front of the massive stones. And then, as in every such place where Nature's work has been done in a manner to attract imposingly, superstition, through long traditions, has peopled the spot with visitors from the dead, or from regions of inhabitants of habits and intelligence differing widely from those of earthly and human kind.

Lohara is situated about 50 miles northeast from Chanda, and about 11 miles north by west from Goonjwye, and at this place, as at Goonjwye, there is a hill of the same kind of iron ore. For about 100 yards, through jungle, and on the slope of the hill from base to summit, one has to walk over fragments of magnetite; specimens of no other kind of rock can be found. The "expression" of the place, as regards the quantity of ore easily obtainable, seemed to me to excel that of Goonjwye. The natives dig for the ore here as at the other place, near the base of the hill, where they find it in small pieces, and thus save labor in breaking it up for smelting. In one place a sinking has been made to a depth of about 20 ft., on a kind of lode of the ore, and widened out into a large space, but this can only have been led to by finding small pieces in such places, as there is a vast quantity of the ore exposed at the surface in large pieces and masses. There is, I think, a probability that the ores here and at Goonjwye are elevated portions of one and the same large lode; as at Dewalgaon, the third and last place I inspected, there is unmistakably a lode of the same ore clearly traceable for at least 150 yards, and running nearly parallel with a line uniting Goonjwye and Lohara. The cardinal lode is about 10 ft. wide, and is filled up with nothing but massive ore; there are, however, forks and branches from this, and small pieces of the ore are scattered over the country for many square acres in extent, as is shown by the various diggings for it for the native furnaces. This place is on the east side of the Weingunga river, and at least 30 miles further from Chanda coal field than Goonjwye or Lohara.

From the Mayo colliery to Goonjwye, or to Lohara, the road is about 65 miles; the roads are good ones for native carts, that is as compared with Indian roads, and, save during the rains, the ores could be carted from the mines of iron to the present only mine of coal in the district for about 12s. per ton. To this sum would have to be added the cost of breaking up the ore at the mines, and filling it into carts, for which I think 2s. per ton would be sufficient. A very large quantity of ore is obtainable in fragments—many hundreds of tons—to load which into carts would not cost more than from 2d. to 3d. per ton; but for breaking up the large blocks, drilling machinery and blasting by gunpowder would have to be resorted to, and would, of course, increase the cost. It is hoped that coal will be found nearer to this valuable ore than the Mayo pit, and then with narrow gauge and cheaply made railways, and Fairlie's bogie-engine train, what may not be done in the way of economic transit of material? No one is more keenly alive to the importance of iron-producing works in India than His Excellency the present Viceroy, the Earl of Mayo; and now that railway extension is to be made on a somewhat extensive scale, it is the flood-tide of time "which if taken will lead on," etc., so far as regards iron works, and His Excellency the Viceroy is wishful to make rails in India for Indian railways, and other requisites in iron material, and why should they not be made, and made, too, in this part of India, when we have the best iron ore in the world, and a fair quality of coal so nearly together, and there, too, are limestone in abundance close at hand?

ON PYROMETERS.

BY C. WILLIAM SIEMENS, F. R. S., D. C. L.

From "The Artizan."

The mercury thermometer which enables us to estimate ordinary temperatures with such admirable precision, fails to indicate heats exceeding the boiling point of mercury (500 deg. Fahr.), and although many attempts have been made to produce a reliable high temperature thermometer (or pyrometer), it can hardly be said that such an instrument is now in the hands of the practical metallurgist.

Amongst the attempts which have been made in this direction the Wedgwood pyrometer occupies the first position. It is based upon the peculiar property of fire-clay to shrink permanently when exposed to intense heat, and upon the supposition that the amount of shrinkage in question was proportionate to the intensity of the heat to which the ball of fire-clay had been exposed. The error involved in this supposition becomes at once apparent if we consider that the shrinkage of the ball is caused by the expulsion of water of hydration which must necessarily take place chiefly at one particular temperature. It is proved, moreover, by the very discordant and, in fact, impossible results, recorded in chemical works as being obtained by means of this instrument. Thus we find it stated in Dr. Lardner's popular treatise, that cast iron melts at a temperature of 17,977 deg. Fahr., and that iron welds at a temperature of 21,000 deg. Fahr., whereas it can be proved that the utmost temperature to be obtained by the combustion of carbon with a blast of atmospheric air, cannot exceed 4,600 deg. Fahr., which degree of temperature far exceeds the points of heat to be met with in metallurgical processes, not excepting even the melting point of mild steel, which comes nearest to the maximum point here indicated.

Amongst the other pyrometers that have been proposed from time to time is the air pyrometer, which is limited by the melting or softening point of the vessel confining the air; the pyrometer by difference of expansion of two metals which has lately been brought forward in a compendious form by Mr. Gauntlet, but which cannot be relied upon beyond a point approaching red heat, at which permanent elongation of the metal sets in; and a pyrometer by contact of two dissimilar metals setting up an electric current capable of measurement, which, however, is by no means proportionately progressive with increase of temperature.

Another pyrometer has been based upon the well-founded supposition that the specific heat of metallic bodies is the same at various temperatures, and that by measuring the heat of a ball of metal after it has been exposed to the heat to be estimated, a true measure of its intensity is obtained. I have myself constructed an instrument upon this well-known principle, which has found considerable favor with ironmasters in measuring the temperature of hot blast, and for other purposes. It consists of a portable vessel composed of three concentric cylindrical vessels of thin copper-plate, the two interstine spaces being filled; the inner one with cow-hair, and the outer one with atmospheric air, and the two together forming an excellent barrier against loss of heat from the interior of the vessel.

A delicate mercury thermometer is fixed in the interior of the vessel, being protected by a perforated shield, and furnished with a movable sliding scale showing pyrometer degrees, of which one is equal to 50 ordinary degrees. The instrument is accompanied by balls of copper or platinum, which are so adjusted that 50 of them would be equal in thermal capacity to an imperial pint of water. Each ball is perforated by a hole through which a rod is passed in exposing the same to the action of the heat to be measured. Immediately before using the instrument, an imperial pint of water is poured into it, and the pyrometer slide is so moved that its zero point coincides with the top of the mercury column in the thermometer tube. The ball is thereupon exposed to the heat for two or three minutes, and plunged into the water. The mercury will be observed to rise, and the absolute temperature of the place measured is ascertained by adding the reading on the pyrometer scale, opposite the new level of the mercury, to the degrees of temperature indicated by the thermometer before

the ball was introduced. In using ordinary dexterity very satisfactory readings may be obtained with this instrument, but its application is limited to the point of heat at which the metal ball employed begins to deteriorate, nor can it be employed for measuring the temperature of inaccessible places.

It has been my endeavor for several years to devise a pyrometer of a more universal applicability, and containing in itself more absolute proof of correctness, and, after a long series of experimental investigations, I have succeeded in producing an instrument which I can confidently recommend to the practical metallurgist. It is based upon the peculiar properties of the pure metals to offer an increasing resistance to the passage of an electrical current with increase of temperature. A platinum wire of known electrical resistance is wound upon a cylinder of fire-clay, upon which a helical path has previously been cut to prevent contact between the turns of the wire. The coil of wires, so prepared, is enclosed within a cylindrical casing of platinum, if the temperatures to be measured exceed the welding heat; or of iron or copper if lower temperature only requires to be measured. The two ends of the coil of wire are brought out endways and are attached within the protecting tube to thicker leading wires of copper, insulated for a short distance by being passed through pipe-clay tubes, and further on by india-rubber, or gutta-percha, terminating at the measuring instrument, which may be placed at any convenient distance. This latter is of peculiar construction, its characteristic feature being that the usual calculations necessary in determining electrical resistances by the Wheatstone or other methods are dispensed with, and a reading in degrees of a large scale is at once obtained by so placing the index lever that the electrical current, generated in a small battery and passed through the measuring instrument, including the platinum wire of the pyrometer, produces a deflection of the galvanometer needle. These degrees do not express the temperature, but the temperature they represent is expressed by the accompanying table of reference, which has to accompany each instrument. The pyrometer coil itself, with its protecting casing, may either be fixed permanently at points, the temperature of which ought to be ascertained from time to time, or it may be introduced into a furnace through a door or aperture for only a minute or two, which time suffices to obtain a reading of the instrument. The latter is the only practicable method where the temperature to be measured approaches a welding heat which would in time destroy the protecting case of platinum or any other material; whereas, the former method of fixed coils will be the most convenient for measuring the lower temperature of drying or annealing stoves, or of the hot blast supplied to blast furnaces. At iron works with a number of hot blast stoves, protected coil may be fixed within the hot blast tube leading from each stove towards the blast furnace, and the leading wires from each of these coils be brought into the office where the measuring apparatus would be placed. By such an arrangement the temperature of the blast of each stove of the furnace could be measured and noted at frequent intervals by a clerk without leaving the office, and very perfect record and control be thus obtained. The correctness of this instrument depends solely on the ratio of increase of electrical resistance in the platinum wire with increase of temperature. This rise is considerable, the resistance being increased fourfold by an increase of temperature from the freezing point to about 3,000 deg. Fahr. The ratio of increase is, however, not uniform, but follows a parabolic law which I have ascertained by a series of careful observations embodied in the table, and which form the subject of a separate communication to the Royal Society. I wish it to be understood that in developing these principles, I have been animated solely by a desire to fill up a blank in the means at our disposal to carry on metallurgical inquiries with such a degree of certainty as could not hitherto be realized without seeking for any commercial reward, through the Patent Office or otherwise.

A STEAM omnibus has began to run regularly between Edinburgh and Portobello, a distance of about 3 miles. The omnibus is constructed to carry 65 passengers—21 inside and 44 outside. The trips already made have been very successful.

THE SHERMAN PROCESS.

From "Engineering."

During the past few years the iron-making public have had brought before them so many "processes" for purifying iron or manufacturing it into steel, with more or less wonderful results, that the advent of a new process, unless it be one possessing more than ordinary claims to notice, has almost ceased to attract any general attention. Notwithstanding this, however, it is an undoubted fact that there is still ample room for improvements in our various methods of iron and steel making, and particularly is there wanted a means of turning to better account the low class irons produced in many districts. Amongst the many workers in this field is Mr. J. Edwin Sherman, who has lately arrived in this country for the purpose of introducing here a "process," of which he is the inventor, and with which, it is stated, very successful results have already been obtained in America. Mr. Sherman has visited England at the invitation of our Government, conveyed through the British Legation at Washington; and the earlier trials of his process made by him since his arrival here were conducted at the request of the Lords Commissioners of the Admiralty and partly under the supervision of one of their officers. Before speaking of these trials, however, let us give what information we can concerning the "Sherman process" itself. And here we may acknowledge at once that this information is exceedingly scanty, so scanty, indeed, that had it not been for the importance of the object which the process professes to attain, and the satisfactory manner in which some of the curious results already obtained by it are vouched for and certified to, we should have hesitated to bring the "Sherman process" under the notice of our readers at all. It is true that Mr. Sherman has patented his process in this country, but as his patent was only taken out on the 25th of July last, it will not be open to inspection until the 25th of next January, and in the mean time its owner prefers to keep its details secret. All that can be said, then, is this: In applying his process to the purification of iron in the puddling furnace, Mr. Sherman melts the pigs in the ordinary way, and then, just at the moment that the "boil" is commencing, he throws into the liquid metal a small packet containing certain chemicals, of which he at present keeps the composition to himself. The effect of this addition is stated to be an increased fluidity and boiling up of the metal, and a rapid throwing off of impurities, thus enabling the iron to be more rapidly "brought to nature" and materially shortening the time occupied in the operation of puddling. The dose of chemicals, or as it has been named by the men, "physic," is so small, and apparently so utterly inadequate to the results claimed to be produced, that it is not to be wondered at that the whole process has been regarded in many quarters with considerable incredulity—an incredulity which we believe nothing but an inspection of the results actually obtained in practice is likely to remove. In applying the process to making cast steel in pots, the chemicals are placed in the crucibles with the iron; while in employing it for rendering common irons available for the Bessemer process, the "physic" is by preference added to the liquid metal as it is being run into the converter, although it is stated that it may be placed in the converter itself, or even in the ladle from which the steel is poured.

So much for the general outline of the "process;" and now for the results which it is stated to produce. Mr. Sherman asserts that by his method of treatment he can "add materially to the value of the best pig-iron made in this country," while he also states that he can produce from the common brands, without admixture of higher class pig, iron which has been pronounced equal to "best best" Staffordshire; and that from cinder and other low grades of pig, each worked separately without mixture with other brands, he can by his process produce good merchantable iron of uniform quality. Further, he affirms that he can produce good tool and other steels of very high tensile strength and ductility, and of uniform quality, from the common pig-irons of this country. These are

certainly startling and apparently somewhat bold statements; but the results which Mr. Sherman has already obtained warrant our regarding them with far more attention than we should otherwise probably be disposed to vouchsafe to them. Mr. Sherman, moreover, offers to prove the accuracy of his statements at any iron or steel works where the necessary facilities and a fair trial will be offered to him; and inasmuch as the application of the process involves no alteration of furnaces or general system of working, there is every reason why his process should be exhaustively tested.

Mr. Sherman's first trials in this country were made, at the request of the Lords Commissioners of the Admiralty, at the works of Messrs. Vickers, Sons, and Co., of Sheffield, and consisted in the manufacture, by his process, of steel ship-plates and samples of tool and other steel, from common English irons. The plates were made from irons selected by Mr. Luke, the Chief Surveyor to the Admiralty, and, the experiments having been conducted under his supervision, the plates were stamped by him, and sent to Chatham Dockyard for the purpose of being tested. The results obtained were very satisfactory, the samples showing a tensile strength of 36 tons per square inch of original section with an elongation of from $1\frac{1}{2}$ in. to $1\frac{13}{16}$ in. in a length of 6 in. The breaking strain, calculated from the reduced area at the point of fracture, was over 60 tons per square inch. Further samples of these plates, which were $\frac{1}{16}$ in. thick, were bent double at a dull red heat, both with and across the grain, without showing signs of fracture, while a piece was also bent double cold, with the grain, with the same result, and another piece was similarly bent *across* the grain with but very slight fracture. Another of Mr. Sherman's samples tested at Chatham, was a $1\frac{1}{2}$ in. square bar of a tough class of steel, named by the Admiralty officials "gun metal." This bar proved to have a tensile strength of 59 tons 645 lbs. per square inch of original section, and its elongation was $5\frac{1}{8}$ in. in a length of 2 ft. This bar was also bent double *cold* without sign of fracture, and a portion of it forged down to $\frac{1}{2}$ in. square, broke with a tensile strain, on the reduced area, of 66 tons 840 lbs. per square inch, the elongation being $1\frac{5}{8}$ in. in 1 ft. Another sample was a piece of tool steel which broke at 73 tons, 755 lbs. per square inch of original section. Tools of various kinds, made of this steel, were tested at Chatham with most satisfactory results. The various samples of which we have spoken, as well as those to which we shall refer hereafter, were, we may mention, exhibited by Mr. Sherman at the recent quarterly meeting of the iron trade at Birmingham, and much attention was attracted by them. Altogether, about fifty samples of various kinds of iron and steel produced by this process were shown.

The application of the "Sherman process" to the production of steel by the Bessemer process from common brands of iron, has been tested at Messrs. Lloyd's, Foster & Co.'s works at Wednesbury with promising results; but the trials were not sufficiently extensive, nor are the data in our possession concerning them sufficiently detailed to enable us to speak of them with any degree of decision. Mr. Sherman is, however, we believe, now conducting some further trials at Sir John Brown & Co's works at Sheffield, which will, we have no doubt, supply the information we desire. The possibility of purifying iron by the Sherman process has been tested at the works of the Darlaston Steel and Iron Company, near Wednesbury, under the supervision of Mr. E. T. Mainwaring, the manager of the works, and judging from samples now in our possession, and which, it is stated, have been produced from common brands of iron, the results are very satisfactory. In this case, however, as in the case of the experiments at Messrs. Lloyd's, we should prefer waiting for more definite information as to the precise nature of the pigs treated, before offering any decided opinion on the value of the results obtained. At the Darlaston Works, also, a few ingots of cast steel have been made from the puddled bars produced by the Sherman process, and this steel has been found to make good tools capable of standing severe trials. One piece of this *tool* steel now in our possession has been drawn down at one end to $\frac{1}{2}$ in. square, and this portion has been bent *cold* into a ring about 4 in. in diameter; while the other end of the sample has been split up for about 6 in., and then welded perfectly.

We may now speak briefly of some

tests, made by order of Rear-Admiral Dahlgren, at the Navy Yard, Washington, of some samples of steel manufactured by the Sherman process at the works of Messrs. Anderson and Woods, at Pittsburgh. These samples consisted of steel bars of various degrees of hardness manufactured partly from Juniata bloom ends; partly from $\frac{2}{3}$ Juniata bloom ends, and $\frac{1}{3}$ Peru, Missouri; and partly from $\frac{2}{3}$ Peru and $\frac{1}{3}$ Swedish iron. These samples gave tensile strengths varying from 95,747 lbs. to 140,056 lbs. per square inch, while the greatest elongation recorded (the elongation not being given in all cases in the official report before us) was 0.3 in. in a length of 5.04 in. A sample having a longitudinal flaw running through it, which had been made by melting down common scrap iron in a crucible, and drawing down the ingot to 1 in. square, broke with a strain of 68,501 lbs. per square inch, while a piece of steel saw blade made by Mr. Sherman's process, and evidently of extreme hardness, is recorded as having broken with a strain of 220,900 lbs. per square inch.

We have now laid before our readers the main facts in our possession concerning the Sherman process, and we prefer for the present to leave them without comment. We hope before long to be in possession of such analyses of pig iron treated, and of the products in the various stages of manufacture, as may enable us to speak with greater authority on the value of the process, and of its future prospects—good or bad, as they may be—than it would be possible for us to do at present; and all we can say here, therefore, is that we trust that Mr. Sherman may have a fair field for his trials, and that he may, before long, be enabled to lay before the public such complete data respecting his experiments as may at once enable iron and steel manufacturers to correctly estimate the value of his results.

BOILER EXPLOSIONS.

By R. WABNER.

Translated from "Der Berggeist."

The possibility that the cause of explosions may be due to explosive gases generated in flues of a boiler has escaped attention. That explosive compounds generally result from the burning of coal no person can doubt. Many a reader has had unpleasant proof that a common stove may be burst by too sudden and abundant coaling. Explosive mixtures easily form in the gas-stove now in general use in Upper Silesia. If the gas flowing from the generator into the large receiver of the stove is overheated and set on fire, a violent explosion follows.

In the same way explosive mixtures may form in the spaces under and near the boiler, which when set on fire must cause violent concussion in the walls, and also in the water and steam contained in it. If the steam-tension in the boiler is very high, and if besides this the walls from long use have lost their original elasticity and resistance, a sudden rupture occurs, or a compression of the walls; the latter a phenomenon not heretofore explained.

The cause of the formation and collection of explosive compounds in the fire and smoke passages is usually to be found in the hindering of the discharge of the fire-gases through the chimney. If, when the fire is at height and coal is just fed, the smoke damper is suddenly closed; or if a partial stoppage of the draft in the chimney is caused by a fall of soot or of the brickwork of the chimney, the consequence is a collection of smoke and unconsumed gases under the boiler; since in consequence of the great heat of the fuel the generation of gas still continues, even when the draft is stopped. The formation of flame also ceases. Atmospheric air rushes in through the doors and grate and mingles with the collected gases, so that the whole mass may be suddenly set on fire; a circumstance that may cause a momentary generation of heat, or a sudden expansion of gas, followed by a violent explosion.

Of course not every collection of gas and sudden firing are followed by an explosion of the boiler; this must also

depend upon a relatively high steam-tension, or a bad condition of the boiler plate.

In view of this explanation the smoke-damper must be considered as the possible occasion of an explosion. The partial closing of the damper must be especially dangerous, since a momentary collection of gases may result, and at the same time atmospheric air be drawn into the fire-chamber. The circumstances attending the frequent boiler explosions lately occurring in Kattowiz have led to this view of the cause ; and this has lately received confirmation from a case of explosion at Bochumer.

NOTES ON A PROCESS FOR THE PRESERVATION OF BUILDING-STONES.*

By A. H. CHURCH, M. A.

From "The Chemical News."

My attention was directed to the subject of the preservation of stone about 1860. In 1862 I took out a patent for this purpose. The process consisted in the alternate application of solutions of pure baryta and pure (dialysed) silica. The plan was partially successful, and possessed the great advantage of causing no discoloration or efflorescence on the stone. But the solutions were rather weak, and, therefore, many repetitions of the process were necessary to secure an effective protection. Then, too, the silica solution failed to penetrate calcareous stone to any appreciable depth, owing to its rapid coagulation. After some years of further experiment, improvements were devised which ultimately resulted in a new and much more successful process. This process, for which a patent was obtained, in 1869, by Ransome's Patent Stone Company, consisted in the successive and repeated application of three liquids. The first of these is a solution of mono-calcic phosphate, often erroneously termed biphosphate of lime, and first introduced, I believe, for a similar purpose, by Coignet. The second solution is one of barium-hydrate, applied warm if possible ; and the third is a dialysed solution of silica, to which small quantities of the ordinary potassium and sodium silicates of commerce have been subsequently added.

It will not be necessary to dwell upon the proper methods of applying these solutions, nor upon the details of their manufacture. I may, however, mention that there is no difficulty in obtaining the various solutions in a state of sufficient purity and strength, and at a sufficiently low rate, to admit of their economical employment for the purpose in view. And it may be interesting to state that the dialysers employed, which are of the capacity of 6 gallons or more, and of an open bell shape, are found capable of doing their work very successfully when floated on or suspended in barrels of rain water, or on rafts in a tank or pond ; the movement of water below the diaphragm or vegetable parchment increases remarkably the rate of separation.

The reactions which take place between the several solutions themselves, and between the solution and the constituents of the objects treated, cannot be described in detail. The mono-calcic phosphate becomes chiefly di-calcic phosphate in contact with a limestone, and then, on the application of baryta, a barium di-calcic phosphate is formed. If decay has already taken place, and sulphates have been formed in the stone, these are converted into insoluble and non-efflorescent barium sulphate, while the lime and magnesia thus liberated immediately become phosphated by the subsequent application of the mono-calcic phosphate solution. The siliceous solution finally employed keeps good some time, and penetrates some distance beneath the surface. It contains, indeed, a small quantity of alkalies, but their amount is not sufficient to produce any soluble salts in the treated stone or bricks. It would be tedious to enter into the proofs of this statement furnished by direct experiment. Extensive trials of the new process have been

* Read before the British Association, Liverpool Meeting, Section B.

made on many important buildings, some of which have been entirely treated by the three solutions described above. I may cite as examples of the use of the process, the Chapter House at Westminster, and the St. Pancras Midland Terminus; portions of Canterbury Cathedral have also been submitted to treatment, together with numerous other buildings, public and private. Where the direction has been carried out with fidelity the results have invariably promised well. No marked alteration of the appearance of the stone is to be seen after the lapse of a few months from the time of using the process. The waterproofing of the stone effected by the use of the solutions is seen in many ways, particularly when after a shower of rain the color of the treated surfaces is seen not to be darkened by absorption of water. A piece of black cloth drawn over a piece of Bath or Caen stone after treatment neither blackens the stone nor is itself whitened by it.

I may add, in concluding this very imperfect notice, that my process is one of those just selected (1870) for the renewed trial at the Houses of Parliament. The specimens exhibited are treated and untreated specimens of the chief stones employed at the Chapter House, Westminster, and at the St. Pancras Terminus.

THE RECENT TORPEDO EXPERIMENTS.

From "The Mechanics' Magazine."

The torpedo question has recently advanced another step towards practical solution, a series of important experiments having taken place at Sheerness and Chatham during the past and previous weeks. These experiments were briefly noticed by us in our last number, when we promised further details both of the torpedoes and of the experiments, and which we now supply. These experiments were made with both moving and fixed torpedoes, the former being tried at Sheerness, and the latter at Chatham, in the presence of the Commander-in-Chief. Taking these experiments in their proper order we will first notice those made at Sheerness with what is known as the fish-torpedo. A few words respecting the history of this apparatus will not be out of place here. Towards the close of last year the scientific world was startled by the announcement that a torpedo of wonderful construction, and possessing still more wonderful powers of offence, was being tried on behalf of the Austrian Government. The stranger hailed from the little port of Fiume, where it might be seen under the strictest surveillance of its inventor, disporting itself in the briny waters of the Adriatic. It was in shape like a fish, and could be made to travel in any direction under water, being self-propelled and capable of moving at an upward or a downward angle in a straight horizontal line or in circles. A general description of this fish-torpedo appeared in the "Mechanics' Magazine" for December 19, 1869, since which time it has found its way into British waters, and was made the subject of experiment by our own Government on Saturday week in the estuary of the Medway. A profound mystery has been made to surround this fish-torpedo, its construction having been carried on at Chatham with the utmost secrecy. We, however, know somewhat of the weapon from our acquaintance with its performances at Fiume, and although its details may since have been slightly modified, yet its general principles remain the same. So by the light of our previous knowledge, and the slight additions that have recently been made to it, we shall be able to give our readers a tolerably clear notion of this new wonder of the deep.

The conception of this torpedo is due to Captain Luppis, a retired officer of the Austrian navy, but the credit of its practical realization belongs to Mr. Robert Whitehead, an English engineer residing at Fiume. Captain Luppis suggested a floating and travelling torpedo, the fore part of which should be filled with an explosive material, the after portion being occupied by the propelling power, which was to be steam. The practical mind of Mr. Whitehead at once saw that this was an altogether impracticable arrangement, and he at once set to work to design a torpedo according to his own notions of what such a weapon ought to be. He gave it a form approximating to that of

the sword-fish, but besides the projecting snout he added a vertical and two lateral projections, which are neither more nor less than triggers, and any one of which impinging upon an object with sufficient force fires the explosive compound, which is placed in the head of the fish-like structure. The body forms the engine-room and the storehouse for the propelling power, which is compressed air, and which works an internal engine by which an external four-bladed screw is actuated. Thus equipped the fish-torpedo is stated to be capable of a speed of from four to eight miles an hour, the average being four. It is fitted with fins for the purpose of guiding it through a tube attached to the torpedo ship, from which it is discharged into the sea for action. We thus have a submarine, self-propelling torpedo, a great improvement upon the crude notion of Captain Luppis.

Upon the occasion of the recent experiments, the "Oberon" was used as the torpedo vessel, having been specially prepared for that purpose. To this end the "Oberon" has been fitted with a tube 2 ft. in diameter, and about 28 ft. in length, which is situated in a line with her keel and some distance below her draught line. This tube is closed externally by a cap, and is divided internally into two portions, each being rendered water-tight by means of pinstocks, which also prevent the admission of water into the ship. The torpedo is passed into the rear portion of the tube upon rollers, and the pinstock behind it being secured, the one in front is opened, and the cap being removed from the orifice, the torpedo is expelled from the tube by a piston arrangement. The fins act as guides, bearing against four rails which are placed at the top and bottom of the tube. As the torpedo passes out of the tube a trigger catches against a s ud in the latter and starts the propelling machinery. As the tube is carried out from the stem of the ship in perfect line with her longitudinal axis, the direction of the submarine course of the weapon is exactly that of the direction of the ship, aim being taken by steering. The "Oberon" is fitted with a set of powerful air-pumps, which are worked by a 12-horse engine, and by which the air with which the torpedo is charged is pumped into it to a pressure, it is stated, of 40 atmospheres, or 600 lbs. per sq. in.

The object of attack on Saturday week was the hulk of the "Aigle," which lies in Sheerness harbor and has long been used as a coal store there. The "Aigle" is about 120 ft. in length and about 30 ft. beam ; she was moored fast at stem and stern with her head to sea, about a quarter of a mile from the fore shore of the Isle of Grain. The "Oberon" steamed out towards the "Aigle" the only visitors permitted on board being Captain Arthur, R. N., Captain Singer, R. N., and Lieutenant Wilson, R. N., the official committee appointed by the Admiralty to investigate and report upon the new weapon. The signal to prepare was made by flag on board the "Oberon" at 1h. 11m., the cap covering the discharging tube being raised twenty seconds later, the ship still steaming straight on to the target. She kept on her course until 1h. 13m. 35s., when she commenced backing hard astern, and was finally brought to a stand at a point apparently about 120 yards from the broadside of the "Aigle"—certainly not more than 150 yards. At 1h. 14m. the flag of the "Oberon" was dipped as a signal that the torpedo had been liberated, and in about 25 seconds a lofty cloud of white foam mixed with coal dust rendered it apparent that the torpedo had exploded against the hulk. The "Aigle" instantly dropped by the stern and her bows quickly came down to the same level, and at 1h. 16m. she was aground from end to end, having been moored in shallow water for the purpose of allowing the results of the explosion upon the vessel to be noted. The effects of the torpedo upon the hulk were very striking, as, indeed, they ought to have been, seeing that the weapon contained a charge of 67 lbs. of gun-cotton, and that the timbers of the "Aigle" were tolerably rotten. An examination of the wreck at low water showed that the starboard side was altogether cleared out for a length of over 26 ft. and a depth of about 10 ft. Half of the main deck was carried away and the remainder broken up, the planking of the upper deck having been started. On the port side of the hull the planking was blown outwards over an area 16 ft. long by 2 ft. deep. In short, the disruptive power of the charge was fully utilized, although we can in no way compare these results with those which would accrue to an iron-built armor-plated ship.

A subsequent experiment was made with a smaller torpedo, discharged from a gig 20 ft. in length, and at about the same distance from the hulk as the previous one. The second torpedo measured 14 ft. long and was 14 in. in diameter, its charge being 18 lbs. of glyoxaline. The discharging arrangement below the boat consists of a line of rollers carried by iron stanchions passing down from each side and meeting beneath. And here we may observe that previously to the first experiment a length of 60 ft. of netting was placed outside the "Aigle," about 5 yards from her broadside—it was made of $\frac{3}{4}$ in. rope, and had 4 in. meshes. The object of this net was to test its efficiency as a protection for a vessel and at the same time to indicate whether at such a distance away the explosion would have any effect upon the hull of the ship. All being ready the torpedo was started on its way, being directed against the netting, in which it was caught, and exploded. Notwithstanding the heavy charge in the torpedo no damage whatever was done by it to the hulk, nor, so far as could be ascertained at the time, to the netting either; so that it was only demonstrated that the torpedo could be caught and would be exploded by such a contrivance.

So far as these bare experiments went the results proved eminently successful, but to our mind there are other requirements which go to make a perfect torpedo, and which are evidently not embodied in Mr. Whitehead's invention. The fish-torpedo undoubtedly does credit to Mr. Whitehead's ingenuity when we consider its ability to move in any direction and at any depth in the water. But it requires many experiments to show whether under the varying conditions of calm and wind, light and darkness, the torpedo can be invariably relied upon for correctness of aim and the distance determined at which it can effectually be run against a vessel. No doubt it was an easy matter to steer the "Oberon" direct on to the broadside of the "Aigle," and to plant a torpedo upon her at a distance of 150 yards only, in the comparatively calm waters of the Medway. If, as the inventor asserts, the torpedo can be run at ships at ranges of from 600 to 700 yards, why was so short a range as 150 yards necessary, except to make sure of the aim and of the explosion of the torpedo, which everybody knew must explode upon contact? If we take winds and waves, tide and currents, weather, and the exigencies of warfare into account, we shall probably find a vessel anchored half a mile off from a torpedo ship to be a tolerably safe place, and a vessel moving at the same distance very much safer. If a steamer has to be run within 150 yards, as the "Oberon" had, and to back and fill and to be brought to a dead stand before delivering her torpedo, we think she stands a very good chance of being disabled by the guns of the enemy before she can complete her mission. What is wanted in a moving torpedo is that it can be guided with certainty towards an object, can be advanced or withdrawn as may be needed, that it can be rendered fatal to a foe and innocuous to a friend, and, above all, that it can be directed unerringly at ranges relatively safe with regard to the position of the enemy's ships. Such a torpedo we believe the fish-torpedo not to be, but the details of such a one we hope shortly to place before our readers.

There is yet another element which has to be taken into account in considering the subject of moving torpedoes, and that is the question of cost. And we are the more induced to look at the matter from this stand-point, because the fish-torpedo appears to be an exceptionally expensive apparatus. The cost of acquiring the right to use it will undoubtedly be something considerable, if proportionate to the prices paid by other countries. When it was first submitted to the Austrian Government, £56,000 was bid for the sole right to its use, the terms eventually being £20,000 for the right to use it in common with other States. The French Government subsequently wished to join with Austria in a monopoly of the weapon, but this proposition was not acceded to—unwisely, we think—by Mr. Whitehead. There can be no doubt but that the English Government will have to pay a stiff price if they want the fish-torpedo. But we might overlook an extravagant price for the right of use, if it were justified by the purchase, which to our mind it is not at present. The expense of manufacture of the fish-torpedoes, too, will be very considerable, the smallest fry costing £200 each. These, moreover, appear to stand their only chance of hitting a ship when well within 200 yards range; what,

then, are the chances of a larger one hitting the mark at 1,000 or 1,500 yards? And then there is the further expense of altering vessels for discharging them from, or of putting torpedo tubes in our men-of-war, as has been suggested, but which alternative we certainly deprecate for many reasons. The very character of the fish-torpedo is impressed with the stamp of costliness; its mechanism is liable to get out of order, necessitating special workmen on each torpedo ship to attend to their use and repair. We give—as, indeed, we have already done—every credit to Mr. Whitehead for his ingenuity, but we cannot give him much hope for the success of his invention as a torpedo to be used out at sea, and for coast and harbor defence we have others better suited to the purpose. For sea purposes, we have not yet seen anything superior to the Harvey torpedo, with which our readers are well acquainted through our columns. This apparatus has proved itself effective in all seas and all weathers, whilst we doubt the efficiency of the fish-torpedo in still water at even moderate ranges, and deny its reliability in a rough sea, and at the ranges required in active service.

The experiments at Chatham were made with stationary torpedoes, and determined some interesting points.

RUSSIAN RAILWAY BRIDGES.

From "Engineering."

Great activity is now displayed, as all the world knows, in the construction of railways in Russia. Upon the whole, the Empire of the Czars does not offer very grave obstacles to the railway engineer, unless, indeed, we except the passage of rivers and navigable streams. These present themselves in considerable numbers; and, as the Russian Government no longer permits wooden bridges to be built, a vast field is being opened for the construction of iron ones. During the last four years iron bridge work has been imported into Russia to the extent of 9,000 tons per annum, while similar iron work has been made in Russia itself during the same period to the extent of 3,000 tons annually. Including the cost of erection, the average outlay upon each ton of bridge work is estimated at nearly £22 10s., so that a very large capital has been and is still being absorbed by the construction of railway bridges in Russia. The Russian Government levies a heavy import duty on iron bridge work imported into its dominions. On the other hand, Russian mechanical establishments are allowed to import raw materials free of duty, the object of the Russian authorities being to encourage by all possible means the development of mechanical industry upon the Russian soil.

The Nicolai or Moscow and St. Petersburg Railway was recently incorporated in the important system known as the Great Russian. One result of the amalgamation has been the overhauling of the way and works of the Nicolai, which are found to stand in some need of repair. The wooden bridges which occur upon the line are also to be replaced by iron ones, the aggregate weight of which is estimated at 12,000 tons. The new bridges will not be made available without considerable difficulties, as they will have to be erected without any interruption of the current working of the line irrespective of great inherent constructive obstacles. Thus a new bridge to be thrown over the Msta (in the room of one destroyed about a year since by fire) will be 140 ft. above the level of the waterway, and its erection must be a very laborious undertaking. Then comes a great bridge over the Neva at St. Petersburg. This work, after having been the object for twelve years past of all kinds of discussions and deliberations, is at last about to be undertaken. If the most recently approved plan is adhered to, this bridge will be something over 1,100 yards in length, and it will rest on twelve or fourteen piers. Its weight may probably be estimated at 6,000 tons.

Contracts are about to be let for bridges on the Smolensk and Brest, and the Woronesch and Rostow lines; the total weight of these bridges is estimated at 5,800 tons. The Woronesch and Rostow line is to be extended eventually to the Caucasus, and a great bridge will in that case have to be thrown over the Don near

Rostow, while several other important works will also have to be executed. Bridges of the estimated aggregate weight of 900 tons occur on the Brest and Grajewo line. A great bridge to be thrown over the Dnieper, near Krementschug, will weigh 3,000 tons. Irrespective of the few bridges thus specially enumerated, it is expected that Russia will establish during the next three years 2,000 versts of railway per annum ; and assuming that 7 tons of bridge work will occur per verst upon these new lines, these works will alone involve 14,000 tons. Upon the whole, it seems clear that for the next three years at least upwards of 20,000 tons of iron bridge work will be annually executed in Russia.

Although the Russian Government is doing its utmost to stimulate Russian industry in every form, it seems extremely doubtful whether Russian mechanical firms will be able, after all, to meet to a greater extent than one-half the demand which will probably arise in Russia for iron railway bridges. Messrs. Struwe Brothers, of Kalomna, contractors for the great Kiew Bridge, whose tools enable them to construct bridges of the largest dimensions, and who have acquired in consequence an eminent position in Russia, cannot produce more than 3,500 tons per annum with their present appliances. The establishments of Messrs. Politika and Semianikoff, at Alexandrowsk, near St. Petersburg, come next in order. These works have been conducted since November, 1869, by a company directed by M. Basson, formerly engineer-in-chief on the Warsaw and Vienna Railway. The works undertook recently the establishment of the Kowroff Bridge on the Nischnei line ; they are pretty well organized, and under their present energetic direction they may, perhaps, turn out 3,000 tons of work annually. Then comes the establishment of Messrs. Lilpopp and Rau, near Warsaw. These works, which recently completed a great railway bridge near Brest, and which are charged besides with the establishment of a bridge near Tiraspol, as well as with the execution of a great part of the bridges on the Moscow and Smolensk Railway—are also in a position to supply about 3,000 tons of work annually. The Bernadaki works, belonging to Prince Tenischeff, at St. Petersburg, might also furnish about 1,500 tons ; but if we combine all these four totals together, we still arrive at an annual aggregate of only 11,000 tons.

There would still seem, then, to be considerable scope for foreign industry in Russia in the matter of iron railway bridge building. According to official data, the railway bridges imported into Russia during the last three years have come from neighboring countries in the following proportions : France, 41 per cent.; Belgium, $30\frac{1}{2}$ per cent.; England, $20\frac{3}{8}$ per cent.; and Germany $8\frac{1}{8}$ per cent. French and Belgian bridge builders enjoy a considerable reputation in Russia, and thus have borne off the largest share of this description of work which Russia has given out to foreign countries. On the other hand, Germany stands better in Russia than either France or Belgium in the matter of locomotive and carriage building. Such are a few details with regard to Russian railway bridges. The railway will achieve a social and commercial revolution in Russia ; and the railway, as has been shown, is dependent to a great extent upon large iron bridges. It seems clear, then, that for some time to come Russia will prove a valuable field for this department of mechanical industry.

Artesian Well in Nebraska.—The labors of the parties who had been boring for the last eighteen months in Lincoln, the capital city of Nebraska, for salt water, were crowned with success. At the depth of 600 ft. below the surface, in a stratum of sandstone, a lead of the great subterranean sea of salt water was recently struck, and the briny torrent came struggling up around the auger and shot into the air some 8 or 10 ft. It has since flowed strongly and steadily, and with great force and increasing strength, forming a briny rivulet. It is believed by the experts who have seen the flow, that when the auger is withdrawn and tubing inserted, a stream of water will be projected from the well to a height of 50 ft., making it the most magnificent artesian well of salt water in the world.—*Nonpareil.*

The average rain-fall at New York city is 49 inches. It is usually called 44 inches.

THE ARCHITECTURAL TREATMENT OF BRICKWORK.

From "The Building News."

When Charles the Second decreed that the rebuilding of London should take place in materials not liable to be destroyed by fire, he did not possibly contemplate the changes he would bring about in the architectural character of his metropolis. The mediæval wooden buildings, and the quaint half-timbered houses which had been erected under the Elizabethan revival of Classic architecture, had now at once to be replaced by structures in brick or stone. And, thanks to the fire, we lost by a stroke of the pen the picturesqeness which seems to have been peculiar to our wooden architecture, and our forefathers were constrained to adopt novel methods of building in fire-proof materials. If we can imagine a body with such authority nowadays as the Metropolitan Board of Works determining, say from January 1, 1871, that no buildings in brick or stone should be commenced in London, we can conceive what an impulse would be given to iron and timber construction; and in 1666, with an entire city of 13,000 houses to rebuild, the demand for architects in these new materials must have been enormous. But the law which teaches us that with the demand must come the supply, held good after the Fire of London, and it soon became evident that the new London was to be a brick city. Indeed, it could hardly have been otherwise; the means of transporting stone were few and limited, and good building stone is nowhere found in the immediate vicinity of the metropolis. Moreover, there was no time to be lost; the chroniclers of that day, Evelyn and Pepys, describe the wretched straits to which the unfortunate citizens were reduced, camping about in tents in all the open spaces round London, and huddled together in the public buildings which had escaped destruction. They did not then doubtless pay much attention to the architecture or to the exterior of their houses, and the revival which was such wonders in Italy played a very small part in the rebuilding of London. Of course, with the masterpieces of Wren and Inigo Jones before us, the Renaissance cannot be said to have been entirely neglected in this country, but, with the exception of the churches and a few of the mansions of the nobility, Classic tradition, at the very period of all others when it had its most important chance, failed miserably to make an impression upon our street architecture. The reasons for this failure will have to be sought for probably in the materials, for it seems an unquestionable fact that the massiveness and grandeur of Classic architecture cannot be translated into brickwork; it essentially requires a stone treatment—or shall we say a stucco one? Luckily that vile sham was then unknown, and we were saved a stucco rival of Rome or Florence, for there is no knowing what Wren might have been called upon to do had Parker or Austin flourished in 1666.

The real cause of the adoption of the "brick-wall-with-holes-in-it" style in London was of course that this was the simplest and cheapest way of sticking square bricks together, and even if we had had designers and manufacturers who could have furnished our citizens with the rich and varied terra-cottas which were then in use in Northern Italy, we question if their wares would have commanded any sale. But it is of no use speculating what might have been the case; we only know what did happen, and we can but regret that for nearly 150 years our street architecture remained devoid of every characteristic. The age which produced Kensington Palace, Marlborough House, and Great Queen street was only better than that which gave us Gower street and Mayfair in that the bricks were better made, and red instead of grey, as the color is now called—dingy black would be a fairer term to express the hue of modern brick-work. The red color of the eighteenth century bricks was due, as is well known, to their being burnt with wood in close kilns, instead of in clamps with breeze as is now practised. The nineteenth century was heralded in with the discovery of stucco, and stucco has probably wrought almost as important a change in the aspect of London as did the Great Fire. To stucco we may attribute all the evils to which architecture is liable. These may be briefly described as bad designs, bad materials and bad construction, and the only comfort in contemplating

a row of stuccoed houses lies in the fact that they are so deficient in durability that few, if any, of them will outlast the ninety-nine years of their leases. The introduction of stucco may, in fact, be regarded as the commencement of the third epoch of London street architecture ; and as the masterpieces of stucco, we cannot do better than refer to the works of Nash, who was its High Priest. In Regent street, which still not unjustly claims to be the finest street in London, we see, or rather we don't see, brickwork revelling in Classic attire, and the terraces overlooking Regent's Park are well-known examples of the transforming power of Parker's cement, as it was at first called. In spite of all our progress in other matters, we are still sticking in the cement period of our architecture, and we can only anticipate by contrast with our contempt of the plain brick-wall treatment (which still, by the way, drags on a lingering existence in remote suburbs) what will be the feelings of the architects of the next generation when they reflect upon our protracted thraldom to this disgraceful sham. With all the grand new squares at South Kensington to build,—for with the vast extension of London northwards and westwards we still go on in the old jog trot routine of stucco squares and stuccoed semi-detached villas--may we indeed dare to hail the Grosvenor mansions as a sign of better times coming as a dove of promise, as an indication that the nobility and gentry will dare to enshrine themselves behind any other material than stucco ? We hope so ! We verily will try to persuade ourselves and our readers, that after 70 years of pseudo Classic civilization, we are going to return to something genuine again, and to allow what we have for some time been showing inside our churches to be seen outside our houses—namely, plain honest brick. If it were not for very joy, we should be tempted to find many faults with the Westminster improvements, and there are to our mind many forms of brickwork better adapted to our street architecture than the pretentious buildings springing up on the outskirts of Belgravia. But we must be contented with small mercies and hope for better times in the future. At the Kensington Museum, and latterly at the Royal Albert Hall, we get entirely another plan of dealing with brickwork, and the attempt to decorate brick buildings solely with terra-cotta constitutes to our mind the dawn of a fourth period in London architecture. If our readers smile at our selection of a few isolated buildings as the nucleus of a style which is to influence the entire architecture of our metropolis, we can but remind them of the insensible way in which this very South Kensington influence has gradually become apparent throughout the country. If in matters of art education we are compelled to admit that we have derived assistance from the existence of the Department of Science and Art, why should we scruple to learn what we can in matters of architecture from the band of art students and art workmen who have received their training at the hands of this institution ? But while South Kensington must be allowed to have led the way to the successful employment of terra-cotta, we can also point to the works of Mr. Barry, who has demonstrated in the most satisfactory manner at Dulwich College that this material can be employed with effect; and there are if we cared to enumerate them, other buildngs, which testify to the growing appreciation of this material for building.

Now when we undertook to write upon the treatment of brickwork, we had in view the possibility of choosing either one or the other of the following alternatives —either, firstly, to consider brick (which, as we have shown, is of necessity the building material *par excellence* of London) in the light of a mere constructive necessity, and to demonstrate that although we cannot avoid it, we may contrive to veil it from the eye by means of some decorative sham, such as ashlaring or stucco ; or, secondly, to look upon brick as a true building material, which should be so considered in the design and so disposed in the building, as to tell as brickwork, and as such to form a part of the architecture. We have shown the reasons for the adoption of brickwork in London, and we have pointed out that brick, and brick alone, was employed for the majority of our buildings during 150 years. We have seen that when stucco was invented, our architecture was so modified that the natural material, brick, was contrained to retreat behind a hideous veil of that wretched sham, through which, however, its constant tendency is, and ever has

been, to show its familiar face, disfigured and deformed by all the unsightliness which bad material and bad workmanship can achieve. And now, in conclusion, we would hail with joy the movement we think we can see the signs of, and which we firmly believe will soon be very apparent, in favor of again employing plain honest brickwork for the façades of our houses and public buildings. We have endeavored to prove that the reason for the ugliness of London is the want of a style of architecture suited to the material, and capable of dealing with the sizes, forms, and color of bricks. After two centuries wasted in hopeless struggles after this style, we believe that neither in Gothic nor in Classic art can these exact requirements be fulfilled, but that to build truly in London we must begin with a brick $9 \times 4\frac{1}{2} \times 3$, and on this form such modifications of the received traditions of order and proportion as are capable of being executed in the materials with which we are dealing. Every one will readily admit that this is the common sense method of treating brickwork, and for the purposes of enrichment, bricks in the form of terra-cotta may receive any amount of decoration. In the best period of all architecture we find the enrichments wrought in the same materials as the remainder of the building, marble for marble, stone for stone, terra-cotta for bricks.

With this appeal to precedent we will leave our readers to form their own opinions upon the correctness of the principles involved in the revival of brick architecture which is now taking place in London, and we can only hope that the conclusions at which we have arrived will be justified by the future of London architecture, and that we may at no distant period revert with satisfaction to the views we have now expounded.

THE DIAMOND FIELDS OF SOUTH AFRICA.

By HENRY HALL, F.R.G.S.

From "The Mining Journal."

North and north-east of the Cape Colony exist vast rolling plains forming a plateau, or table land, of an average height of 4,000 feet above the sea, studded over with innumerable detached kopjies, pointed or flat-topped hills of moderate elevation (spitz-kopjies or tafelbergen), which gradually decrease as we approach the Vaal River, of basaltic or green porphyritic rock protuded as it were through the more recent sandstone or conglomerates of the lacustrine formation, which cover the whole region in almost horizontal layers. These plains are fringed round from the north-east to the south-east, an extent of many hundred miles, by high and, on one side, precipitous mountain ranges. The Plombergen, Maluti, Quathlamba, Drachenberg, and Magaliesbergen, varying in height from 5,000 to 10,000 ft., which, forming the watershed of two different branches of the Gariep or Orange River and its tributaries, the Vaal, Caledon, Hart and Modder rivers, rise in escarped faces on the coast side like gigantic buttresses supporting these lofty plains, and separating them from the lower terraces of the Cape Colony, Kaffaria, Natal, and Zululand. It is not more than half a century ago since these regions attracted the attention of the Cape colonists, first as the scene of the murderous forays of the Zulu tyrants, Chaka, Moselikatze, and Dingaan, whose warriors almost extirpated the more peaceable Betjimana tribes who inhabited the land, and the remnant of whom, forming the Abasutu tribes of Mocheshi, took refuge in the inaccessible valleys of the Maluti mountains, where they still preserve their independence; and more recently as a vast hunting field, first described by Captain Harris, in 1836, as teeming with elephants, rhinoceri, giraffes, and all the larger species of antelopes—the former quite, the latter nearly extirpated.

Then, in a political point of view, came the exodus of the Cape Boers from that colony, and their settlement on the Orange River plains and Natal; the wars consequent thereon; the final withdrawal of the British rule, which, in the first instance, had been extended to this region; and the establishment of the two South African Republics, the one north of the Vaal River called the Trans-Vaal, and the

other in the region between the Vaal and Cape frontier, which in that direction is the Gariep or Orange River, called the Orange River Free State. Two listless communities, devoid of any seaboard or port, with the inhabitants leading a life without excitement, vegetating rather than living on the vast extent of monstrous treeless plains of 10,000 or 15,000 acres each, called "places" or farms, although in Europe they would be called estates; wandering about with their sheep and cattle from one green spot of pasture to another, being much in the style of the ancient Patriarchs, in a very similar region between Palestine and the Euphrates; while the customs dues on all the articles of foreign produce they consume go to swell the exchequer of the British colonies of the Cape and Natal, in whose harbors they are landed.

Events, however, have been lately occurring on these plains, and along the banks of the many rivers, or rather watercourses, which intersect them, and which run but for a few months of the year, but which, after heavy rains or thunderstorms along the tempest-riven peaks of the Drachenberg and Maluti ranges, pour down perfect avalanches of debris, composed of gravel, pebbles, and other alluvial deposits into the turbid waters of the Vaal or Yellow River, the Modder or Muddy River, and the Gariep, Orange or Great Black River, and which in the dry season, when the soluble matter has been washed away and deposited in the shape of mud on the banks, exhibits, on the shoals and shallows of the stream, beds of pebbles containing agates, camelians, jaspers, in great variety, and well-known to collectors of mineralogical specimens at the Cape as "Orange River pebbles." These pebbles are often curious and beautiful, and contain many rare specimens if examined by an expert; but they are too numerous to be deemed of any value, and are principally regarded fit for chimney ornaments, card-counters, and such trivial purposes, and few go to the expense of preparing them under the hands of a lapidary, so as to properly develop the beauties they really possess. As early as 1819 the missionary Campbell, who first explored the course of the Orange River, from its junction with the Vaal, in lat. 29° 20′ S., and lon. 23° 30′ E., to its embouchure on the west coast, describes a portion of the region he passed through as covered with pure crystal pebbles, sparkling in the distance like diamonds, and many other travellers mentioned the agates, jaspers, camelians, of the Orange River countries, supposing them to be the products of the disentegrating peaks of the surrounding mountain ranges.

The geology of South Africa rests on such imperfect data, and the extent of the penetration of basaltic or porphyritic rocks is so roughly defined, that we can here give but an imperfect theory of the region in which the diamond discoveries have taken place. These plains, it is supposed, have been formerly the bed of a vast freshwater sea or lake. Many miles down the Orange River, towards the ocean, violent volcanic action has, at a remote period taken place, forming the great falls of "Aukrubies," 150 ft. in height, and so creating an outlet for the inland waters. Denudations seem, consequently, to have occurred to a great extent, and various little kopjies or hillocks of diluvial matter, composed of quartz, agate pebbles, jaspers, and appearing as if deposited by eddies or whirlpools, occur on both sides and in the neighborhood of the watercourses; and on these little hills the clearest testimony shows diamonds have been recently discovered, in conjunction with conglomerate masses, cemented together with oxide of iron, tufaceous limestone, and other similar rock-forming substances.

The writer of this article lived for many years in South Africa, and is familiar with the localities in which diamonds have been found; but he never recollects a hint being given during that period that such treasurers really existed, although he has heard of, and seen, small rubies, sapphires, and amethysts, but of such a size as to be nearly valueless. It is now four years ago since the first diamond was discovered and sent to Cape Town. There is a few miles south of the Orange River near the northern boundary of the Cape Colony, and about 600 miles north-east of Cape Town, an obscure village, or seat of magistracy, called Hope Town, where the seat of the local government for an extensive tract of a thinly inhabited country being fixed, a church being founded, and possessing good water advantages, a cluster of houses, shops, and stores, for the supply

of the neighboring farms, sprung up, and from this Hope Town the first rumor of the diamond-bearing region along the banks of the Vaal and Orange rivers reached the ears of the commercial community at Port Elizabeth and Cape Town. A very fine diamond of the first water, valued at £500, fell into the hands of a trader there, who purchased it for a trifle from a native, amongst whose children it had passed for a plaything, paying for it, we imagine, a few sheep, cattle, or a wagon, which to a native is a fortune in itself. Many more of these shining stones (even uncut diamonds shine amongst their quartz companions) by degrees found their way into the hands of the little Hope Town winklers, as retail dealers are called in the Cape patois.

These discoveries were hinted abroad, and at last reached the ears of a celebrated firm of London diamond merchants, who sent a trusted agent out to make inquiries. Like almost all European geologists who for the first time visit the lacustrine deposits of South Africa, he made a most egregious mistake, and declared the supposed find of diamonds must have been what is called in slang language a "plant" made by some land speculator who wanted to dispose of his farms, but that in a geological point of view, it was impossible that diamond beds could exist in that region. He might perhaps be strictly right, but he appears to have entirely overlooked the vast physical forces that carried and deposited them there. The same earth-throe that formed the Zambesi Falls of Livingstone, having probably at the same time made those of the Orange River, and draining the inland sea, covered the plains of the Vaal River with the diamond debris of the disentegrated peaks of the Maluti mountains.

Time went on, the public were still incredulous, but by degrees one diamond, then half-a-dozen or more rough and uncut were offered for sale in the Port Elizabeth markets. The Governor, Sir P. Wodehouse, was known to have purchased several, and the house of Mosenthal & Co., a Cape commercial firm of repute, were reported also to have invested largely though quietly in the same speculation; but it was not until the close of the second year, 1868, that the colonial world was startled by the announcement that a diamond of pure water had been picked up weighing 83½ carats. There is some obscurity about where it was found and by whom, but it eventually came from the hands of the native finders and intermediate traffickers, into those of Messrs. Mosenthal, for a considerable sum; was deposited for some time in the hands of the Cape Government, and eventually sent to Europe in the spring of 1869, under the name of the Star of South Africa. It remained in London some time, was cut in Amsterdam, and although considerably reduced in weight, turned out a splendid brilliant, and was sold for a considerable sum—£14,000, we are informed, some say £24,000. After the discovery of the Star of South Africa, a regular *furore* sprung up for diamond digging, and thousands of the already sparse population of the Cape Colony and Free State are still flocking to the banks of the Vaal River, where, near the Mission Station Pniel on the south, and Hebron on the north side of the river, the principal finds have as yet been made of diamonds of all sizes, from 1 to 50 carats, besides a considerable quantity of the valuable, though inferior, diamond "Bort," used for cutting and polishing purposes. Although the appliances used are of the most make-shift nature, and the majority of the diggers totally inexperienced—few of them, probably, ever having seen a rough diamond before in their lives—within the last few months diamonds to the value of £100,000, very lowly estimated, have already been found, being an average of an earning of about 15s. a day for all those employed, now about 3,000; many of whom, however, have been as yet unsuccessful.

The romantic stories in the Cape papers, though not altogether devoid of truth, must, however, be taken *cum grano salis*. Many a digger may believe himself in possession of a real gem worth many thousand pounds which may turn out a worthless quartz pebble, while, on the other hand, in every shovelful of gravel hundreds of small diamonds, all of some value, may exist, and may be thrown aside, owing to the perfect inexperience of the "diamantzockers," as the Dutch boers call the diggers. In the meantime the value of landed property and produce of every kind in this once desolate region has marvellously increased. The Presi-

dent Pretorious, of the Trans-Vaal Republic, has laid down his baton of office, taken up pickaxe and shovel, and enrolled himself among the band of diggers, with all his officials with him. We find in the list of diamond seekers clergymen, medicos, Government clerks, and officials of high degree, farmers, officers of the army, two of whom, from Natal, it is said, have realized £15,000 in a few weeks. A sort of provisional government has been formed, and order and regularity exist to a wonderful degree ; nor are the *agremens* of life altogether wanted, as we find at the diggings billiard tables, Christy minstrels, soda-water machines, etc.

We must not be surprised, however, to find many, both diamond seekers and buyers, disappointed, as in our judgment the prices said to be given for uncut diamonds at the diggings are far more than cut stones could be purchased for in London, Paris, or Amsterdam. Pniel and Hebron, where the principal explorations are going on, are stations of the Berlin Mission Society, near the great bend of the Vaal River. The missionaries very injudiciously levy a tribute on all diggers of 25 per cent. on the value of the diamonds they find, instead of demanding a moderate sum for a license for digging ; this causes much concealment of diamonds found, on the digger's part. In a similar manner these worthies taxed heavily a few years ago parties seeking copper mines in Namaqualand, making the infliction worse by declaring it was for the "sake of the Lord." In the latter case it was also the Berlin or Rhenish Societies who profited, while their titles to the soil were in many cases anything but indisputable. The Pniel and Hebron diamond fields are about 800 miles from Cape Town, *via* Beaufort West, and 650 from Port Elizabeth, *via* Colesberg. The roads are in general good, and the use of bullock wagons enables parties of diggers to carry the necessary supplies with them, which on the spot would prove very expensive.

The following extracts from the correspondence of many respectable and trustworthy persons who have visited the diamond region may prove interesting. Mr. Cooper, of Cradock, writes to Dr. Grey, of the same place :—"The position in which the diamonds are found is a complete enigma to me. The richest find has been on the top of a 'kopjie,' perhaps 100 feet above the river. Indeed, the present run of the river has nothing to do with the find of the diamonds. The whole country must have been submerged, and the matrix in which the diamonds are found must have been deposited in the run of the inundation, current, lake, or body of water. The matrix is found upon and between the chinks of the rocks. The surface is strewn with fragments of rocks and metamorphic sandstone, I think pudding-stone, quartz, and also ironstone. I do not think any of these rocks are abrased by friction ; their edges are more or less rounded off, but this arises, I think, from decomposition. Diamonds continue to be found daily ; yesterday a 29½ carat, and the day before a 17½ carat, besides many smaller." Another correspondent says :—"In regard to the constituent stones of good diamondiferous gravel, satisfactory information cannot be got. Some diggers prefer a light-colored and sparkling gravel, others again are in favor of a dark-colored pebbly soil. Rotten ironstone or basalt pebbles are considered a favorable sign ; gravel with quartz fragments, not water, more the contrary. For many reasons I am inclined to think the best indications are garnets (spinel rubies), and peridot, a blue transparent crystal."

Another writer, Mr. Gillfillan, late of the Royal School of Mines, in an interesting letter to the Editor of the "Grahamstown Journal," mentions :—"Undoubted diamonds deposited here (junction of Vaal and Modder rivers), conglomerate and yellow schist, pebbles of black and red jasper in highly ferruginous soil, stratification of rock horizontal. All the pebbles and crystals in this ferruginous soil are coated with a thin deposit of oxide of iron. I examined a stone in the possession of a Hottentot, about 3 carats, a rhombic dodecahedron ; owner refused to sell. It was of first-rate water, but speckled and flawed ; value about £30." As the diggings are developed, he will perhaps be able to add a second part to the present article, as it is highly probable, owing to the volcanic disturbances in the lower course of the Orange River, and the metalliferous region of Namaqualand traversed by it, that mineralogical discoveries will be made there which may turn out of the first importance.

NEW ELECTRO-DYNAMIC LAW.

By H. HIGHTON, M.A.

From "The Chemical News."

Will you allow me to announce in your journal a new and important electro-dynamic law or laws. The new reasonings and experiments by which they are supported, I hope to enter on more fully in the next number of the "Quarterly Journal of Science." Meanwhile, I submit them to the judgment of physicists for examination and approval, or otherwise.

1. In every galvanic circuit, the net heat produced by the chemical decomposition is divided into three parts—(*a*) due to merely local action arising from the impurities in the positive metal, or the reformation of water from the nascent hydrogen; or (*b*) that which circulates through the battery and all other parts of the circuit, and which varies as the electro-motive power of the negative element in relation to the electro-positive; and (*c*) the residue which remains in the battery.

2. That part which circulates through the whole circuit, is distributed in each part of the circuit, including the battery, in simple proportion to the resistance of each part.

These laws are thus expressed mathematically :—

Let H = total net heat produced;
H_1 = heat produced by waste local action on the positive metal;
H_2 = the quantity put into circulation;
H_3 = the residue not put into circulation.

Then, of course—

$$H = H_1 + H_2 + H_3;$$

and

$$\frac{H_2}{H_2 + H_3} = E,$$

E being the electro-motive force of the negative element in relation to the positive element used.

Also, if H (*b*) be the total heat evolved in the battery when the circuit is closed :

$$h\,b, = H_{(1)} + H_{(3)} + H_2 \frac{R}{R + r}$$

$$h(x) = H_2 \frac{r}{R + r}$$

and if r'_1), r'_2), $r_{(3)}$, be the resistance of different parts of the circuit; and $h_{(1)}$, h'_2), $h_{(3)}$, the heat evolved in those parts;

$$h_{(1)} = H_2 \frac{(r_1)}{R + r}$$

$$h_{(2)} = H_2 \frac{r_2}{R + r}$$

and so on. Again, if

$$H_{(3)} = 0 \text{ or } \frac{H_2}{H_{(2)} + H_{(3)}} = 1$$

then the electro-motive power of the negative element is perfect as relates to the electro-positive element.

In a circuit of zinc in sulphate of zinc, and copper in sulphate of copper, E = 1, or the whole heat produced is transmitted; with zinc, strong sulphuric acid, and platinum, E = about $\frac{5}{6}$, but varies with the strength of the acid; with iron in sulphate of iron, and copper in sulphate of copper, E = about $\frac{2}{3}$; with copper in nitrate of copper, and silver in nitrate of silver, E = about $\frac{32}{82}$.

The total electro-motive force of a couple depends partly on the net heat evolved, partly on the proportion of it transmitted through the circuit. The former depends principally on the positive element, the latter on the negative element.

Some researches have recently been undertaken by Von Pettenkofer on the amount of evaporation which takes place from the foliage of plants. The experiments were made in the case of an oak tree, and extended over the whole period of its summer growth. He found the amount of evaporation to increase gradually from May to July, and then decrease till October. The number of leaves on the trees were estimated at 751,592, and the total amount of evaporation in the year at 539.16 cubic centimetres of water for the whole area of the leaves. The average amount of rain-fall for the same period is only 65 cubic centimetres; the amount of evaporation is thus $8\frac{1}{2}$ times more than that of the rain-fall. The excess must be drawn up by the roots from a great depth; and thus trees prevent the gradual drying of a climate, by restoring to the air the moisture which would otherwise be carried off by drainage.

REGULATOR OF F. R. VAN SCHWIND.

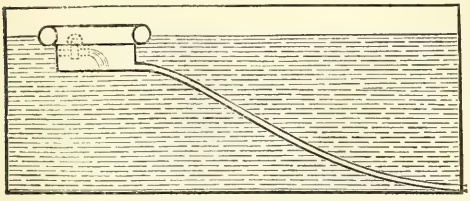
Translated from "Polytechnisches Journal."

In my experiments in the solubility of rock salt I required a running stream of water of exactly uniform discharge, and contrived the apparatus here described.

The reservoir consisted of a small box of wood, sheet-lead or copper. The dimensions were 20 cr. wide, 50 cr. long, 25 cr. deep, so that a sinking of 1 cr. gave a volume of 1,000 cubic cr. or 1 liber, and the contents and variation were indicated by a graduated glass tube.

Near the bottom of the vessel at one end is a small round orifice in which a tube 5 mill. in diameter is inserted water-tight, projecting within and without 1.5 *a* 2 cr.

The float consists of a rectangular frame, 11 × 4 cr., made of sheet-lead 2 cr. wide, soldered water-tight. Within this is a sunken box 11 cr. wide by 4 cr. deep, also soldered water-tight. At the middle of the vertical wall of this box a hole is bored, into which is inserted a fine tube of about 4 mill. bore, so that it lies within the float and can be handled from above. In the opposite side another opening is made close to the bottom, into



which is fitted a lead tube 5 mill. in diameter and 15 mill. long. A tube of gutta-percha 30 cr. long and 5 mill. in diameter connecting the discharging orifice of the reservoir with the tube of the float completes the apparatus.

If the reservoir is filled with water the float rises, and the water can flow into it only through the pipe into the float, from which it passes out of the reservoir through the gutta-percha tube.

The discharge is uniform until the float comes in contact with the bottom; for the depth of the centre of the pipe discharging into the float below, the free surface obviously remains constant as long as there is water enough in the reservoir to keep the float free from the bottom.

This apparatus can be used in feeding lamps, and, with greater dimensions, for supplying water wheels.

The longer the frame in the direction of the pipe, and the longer the pipe, the more constant the action of the apparatus; so that where great exactness is required the frame should be made as large as possible; the box and pipe to be set as far as may be from the orifice of discharge.

As a result of a lengthy series of experiments, M. E. Baudrimont concludes that tin-foil, in consequence of its impermeability for water, may serve with great effect to protect various substances from the effects of the atmospheric moisture, as well as act as a protective against the alterations fruit undergoes by evaporation of the fluids therein contained; tin-foil also protects against the oxidizing action of the oxygen of the atmosphere, and may hence serve to keep fatty substances from becoming rancid, while it may usefully serve in laboratories to wrap up caustic lime, bisulphite of soda, and similar substances, which may thus be preserved for a great length of time without deterioration.

Dr. W. Stein has devised an easily-executed process for the detection of madder colors upon cloth or by themselves. He boils the cloth with a concentrated solution of sulphate of alumina, whereby a liquid is obtained of reddish color, exhibiting a golden-greenish fluorescence, due to the presence of purpurine; the behavior of the coloring matters of madder towards sulphate of alumina is so characteristic that this salt may serve as an effective test for these substances; the alizarine may be readily rendered soluble by treating the dye material or dyed cloths with alcohol acidified with hydrochloric acid.

As a matter of scientific intelligence, we hear the Suez canal has passed into the hands of an English Company.

DRAFT IN CHIMNEYS.

Abstract, translated from the "Zeitschrift des Vereines Deutscher Ingenieure"

Meidinger of Carlsruhe, in an article published in the "Badischen Gewerbezeitung," 1867, p. 26, describes an apparatus illustrating the draft of chimneys. It consists of a tin tube bent at right angles, one leg vertical, the other horizontal. At the end of the horizontal portion a light is placed. The vertical tube (450 millim. long) is fitted below with a removable damper, while the upper end is made so that caps may be fitted to it. The horizontal leg is 240 millim. long; both portions have a clear diameter of 36 millim.

To prevent too great heating of the horizontal branch, it is surrounded with a closed envelope of tin 42 millim. in diameter, having in its upper end a small orifice, so that it can be filled with cold water. The vertical branch is also enclosed in an envelope of tin 54 millim. in diameter, which is intended for holding fluids.

To imitate the wind a double-acting bellows of moderate power is used. The air from this is carried through a long caoutchouc tube into a glass tube 300 millim. long, drawn at the end to a diameter of 6 millim. By means of this, a stream of air can be sent into the upper portion of the apparatus from any required distance and from any direction.

The upright part of the apparatus represents the chimney, the horizontal portion the furnace, and the light at the end of the latter the fire on the grate.

The cause of draft in a chimney is the ascent of a current of air, which may cause an after-current of cold air through the furnace in two ways. Every moving body of air tends to cause a vacuum by making the air behind it rarer. In this way the external air is drawn into the furnace by the motion of the air in the chimney. This is neatly shown by the apparatus. If a light is placed before the horizontal tube the flame burns quietly in a vertical direction; but it is drawn immediately into the tube if a blast of air is blown upwards through the glass tube inserted from below into the upright branch. The flame keeps its horizontal direction as long as the blast is in action. That a draft is caused in locomotives in this way is well-known.

But in ordinary chimneys the operation just described is quite insignificant; in these the effect of heated air must be considered. The heat of the burning fuel expands the air and makes it lighter. The denser and colder air from without is forced in to restore the equilibrium, and passes out from the chimney with a temperature greater than that of the external air. It is therefore clear that the draft will be stronger, the greater the difference of temperature between the heat of the air within and that without the furnace. The draft and the combustion become very great after the fire has burned for a little while. This is also shown by the apparatus. For, when the flame has for some time been under the action of the blast, it continues to burn in a horizontal direction, if the bellows is removed and the cover is immediately applied to the lower end of the upright tube. But the flame resumes its upright direction if the tube remains open. This illustrates the bad effects upon draft of furnaces that have a common chimney when not heated and left open.

Draft increases with the height of the chimney as the square root of the height. This is only true of upright flues.

There is a well known distinction as to diameter between wide (German) and narrow (Russian) chimneys. The latter have a much stronger draft, because warm air fills them throughout, so that a rising of the whole column of air takes place; while in wide chimneys the cold air can enter from above, withdrawing much heat from the rising air and weakening the draft.

The material of the chimney-walls has an important influence upon draft, as the temperature of the column of enclosed atmosphere is dependent upon it. Iron chimneys by rapid cooling cause a weaker draft than those built of stone.

As soon as the temperature of the chimney-walls and the atmosphere within is higher than that of the external air there will be a rising current of air; and, on the other hand, there will be a backward current if the external air is warmer than that contained in the furnace. This is also neatly shown by the

apparatus. If the tube enclosing the upright leg is filled with warm water, the direction of the flame shows an upward draft; but if it is filled with a cold mixture of 7 oz. muriatic acid and 11 oz. Glauber's salt the flame moves outward showing a reverse draft.

Such a reverse draft often makes it very difficult to kindle a fire; the chimney must sometimes be heated by a quick fire of straw, paper, etc., in order to cause a rising current of atmosphere.

When the walls of a chimney retain a high temperature for a long time, an upward draft continues; this is even the case in dwellings that are not heated, as long as the temperature of the house is somewhat higher than that of the external air. If mild weather suddenly sets in, so that the temperature without rises, a reverse draft takes place and lasts until equilibrium is restored.

The apparatus illustrates the influence of wind upon draft very clearly; showing that it is not the chief hindrance of draft, and that it is often a help.

If a horizontal stream of air is blown over the apparatus at a height of about 10 millim., the flame is sucked in; the effect is greater if the stream is directed a little upward.

If the horizontal stream is directed so as to strike the tube a little below the end, a stronger draft upon the flame follows. The current is condensed and glides off the surface, causing a current that puts the column in the tube in motion.

If the horizontal stream is directed upon the opening, the blast-tube being applied to the edge of the chimney, the flame is blown away by a reverse draft. The reason is, the blast of air from the bellows-tube expands conically, setting in motion the adjacent layers of air, and with them the air in the chimney. This is forced backward by the stream consequent upon the concussion and condensation upon the walls.

The operation of the wind does not correspond to any of these cases, but rather to all combined. Natural wind can be imitated enough, if the end of the bellows-tube is held at a distance of 600 millim. and directed towards the upper end of the tube. Part of the conical stream in this case strikes the tube, while the upper portion passes over in a direction nearly horizontal. A lively draft is the consequence, showing that the wind draws the column after it. The current reflected from the tube and the horizontal current above form a resultant which is inclined above the chimney, but soon becomes a horizontal. An upward direction of the blast increases the draft as long as the angle toward the horizontal angle is not greater than 15 deg. The resultant then passes over the chimney in a horizontal direction. A larger angle causes a reverse draft. We see here why a person standing on a tower or bridge with a high balustrade is not struck by the prevailing wind, while he can feel with his hand the current coming upward against the wall below, and coming downward above his head.

The effect of chimney caps may be illustrated by the apparatus.

A collar or cornice is often put on chimneys as an architectural finish. Experiment with the apparatus shows, that these have an injurious effect. For this cornice catches the rising current, so that the horizontal wind alone acts and causes, as above shown, a back-draft. If there must be a collar, the chimney tube should rise above it at least 600 millim.

A horizontal plate set at some distance from the mouth of the chimney has a different effect.

Though this was at first used only as a protection against rain, it is the best means of preventing all injurious effects of wind. In experiments with the apparatus when provided with a plate, whatever may be the direction, and the force of the current of wind, the flame is drawn into the tube. The dimensions and position of the plate have an important influence. According to Meidinger's experiments, the plate should have a diameter double that of the chimney, and a light above its mouth equal to two thirds of the diameter. This contrivance makes it unnecessary to raise a chimney that opens under the peak of a gable roof.

A means has been lately devised in France, as protection against the wind, which has been applied in several chimneys at Carlsruhe. It consists of a cap of two plates crossing at right angles, pointed above, which are inserted into the chimney. The intention is, that two openings may remain open if the others are closed by the wind. The apparatus

shows that this does not happen, as in all cases wind is blown into the chimney.

Experiments with Wolperts & Noeggeratti's caps (described in the "Zeitschrift des Vereines," Bd. XIII. and XIV., gave favorable results.

THE ILLINOIS AND ST. LOUIS BRIDGE.*

THE WEST ABUTMENT.

The masonry of the west abutment has been completed from the bed-rock of the river to a point 31 ft. above low-water mark. From the bed-rock to the top of the masonry, the height is now 44 ft. Eight courses of granite are laid on it and two courses, or 5 ft. are required to complete it to the skew-backs against which the steel ribs of the western span will rest. This mass of solid masonry stands upon the lower edge of the wharf in St. Louis, and measures at its base, in the direction of the river current, 94 ft., and transversely 62 ft. 9 in., and contains at this time 6,380 cubic yards of masonry. When completed to the carriage-way, it will be 115 ft. high above the bed-rock of the river, and will then contain 11,860 cubic yards of masonry.

The work on it is going steadily forward in a satisfactory manner.

Although the bed-rock at the site of this abutment is 73½ ft. higher than at the east pier, the difficulties encountered in building its foundation were of a much more perplexing and tedious character than those encountered at either of the others. Its site had been for over 60 years a part of the steamboat wharf of the city, and, as such, had received every kind of useless material thrown overboard from the various steamers lying over it during that time. The old sheet-iron enveloping their furnaces, worn out grate-bars, old fire-bricks, parts of smoke-stacks, stone-coal cinders and clinker, and every manner of things entering into the construction of a Mississippi steamer, seemed to have found a resting place on this spot, and constituted a deposit averaging 12 ft. in depth over the rock. During the memorable fire of 1849, when 29 steamers were destroyed at the levee, the wrecks of 2 of them sunk upon the site of this abutment. One of these was partly covered by the hull of the other, which probably sunk immediately afterwards. The lower one was but 2 or 3 ft. above the bed-rock. After this terrible conflagration, the city authorities determined to widen the wharf. Its front was extended to a line inclosing about one-half of these two wrecks, by filling in with stone and rubbish from the city. During this extension, several other vessels were burnt at the wharf, and the wreck of one of these also sunk upon the site of the abutment. The coffer-dam, constructed to enclose the site, had to be put down through these three wrecks, the hulk of either of which was not probably less than 400 tons measurement. Their bottom planking was all of oak, 3 or 4 in. in thickness. To drive the sheet-piling down through these hulks, an oak beam 6 by 10 in. sq. armed with a huge steel chisel, was first driven down as far as a steam pile-driver could force it. It was then withdrawn and a sheet-pile, 5 by 10 in. sq. was driven down in its place. The coffer-dam was formed of two courses of sheet-piling, 6 ft. apart, which were filled in between with clay. When this was completed, the water pumped out and the excavation prosecuted within it, the discovery was made that from one-third to one-half of the length of each of these three steamboat hulks was enclosed within the dam, and that some of the sheet-piling had not been driven through the lower one, owing to the great resistance of the hulk and the mass above it. Before the space between the lower wreck and the bed-rock could be made secure on the inner side of the dam, the water came through and flooded the inclosure. A stream from a powerful Gwynne pump, having an 8-in. diameter of jet, was then directed against the material deposited over these wrecks on the outer side of the dam, where the water was 15 ft. deep, and enough of the deposit was washed away to enable another course of sheet-piling to be driven down 6 ft. beyond the dam, through all of the

*Extracts from the forthcoming report of the Chief Engineer, Capt. James B. Eads.

wrecks to the rock. After this that part of the wrecks enclosed between this last course of piling and the dam, was removed by a diver and the space filled in with clay, and the inclosure again pumped out. This portion of the dam, about 50 ft. in length, was by this construction made double. As the excavation within progressed, it revealed the fact that another portion of the dam had been built and made water-tight through and over a water-wheel of one of the wrecks. The crank of an engine of 7 ft. stroke attached to the head of the shaft of the wheel, was just within the inclosure, while the flanges, arms, and braces of the wheel were within the walls formed by the sheet-piling. From the inclosure within the dam were taken parts of several old and burnt steamboat engines, the iron parts of some of which had to be cut off at the dam. Four wrecks of barges, some of them in use doubtless before the era of steam, were also found within it; likewise several oak saw-logs, some anchors, chains, and a great variety of smaller articles lost or thrown overboard from the river craft, or dumped in from the city.

This incongruous deposit made it exceedingly difficult to maintain the integrity of the dam, which at times had to resist a pressure of 30 ft of water. Frequent floodings consequently occurred which delayed and increased the cost of the work. These difficulties were, however, finally overcome, and the bed-rock within was at last exposed to view.

On the 25th day of February, 1868, after thoroughly testing the solidity of the rock by drilling, the first stone of your bridge was laid in this abutment 55 ft. below high-water mark, about four months after commencing the construction of the dam.

THE EAST PIER.

The caisson for sinking the East Pier having been completed, and the requisite guide piles, air and sand pumps, hoisting machinery, etc., being made ready, it was launched from the ways at Carondelet, on the 18th of October, 1869, and was towed up to its position in the river and duly secured within the guide piles on the same day. Some days more were occupied in securing the caisson to the suspension screws that were to steady it until it reached the sandy bed of the river, and in connecting the various air and water-pipes with it. On the 25th day of October, the first stone was laid upon it, from which moment until it reached the bed-rock of the river, on the 28th of February last (128 ft. below high water mark, or 120 ft. below the city directrix), the progress of its descent, and the working of the machinery connected with it, were marked by an almost total freedom from accident.

During low water the normal depth of sand over the bed-rock at this pier is about 80 ft. A rise in the river causes it to scour down, whilst a subsidence of the flood permits the moving sands from above to deposit rapidly and again raise the sand bed. At the time of placing the caisson in position the water in the river was 35 ft. deep, and 68 ft. of sand were then overlying the rock. As the caisson descended, the current sweeping under its bottom at the rate of about $3\frac{1}{2}$ miles per hour, caused a further scour of 5 ft., leaving an irregular surface of sand, averaging about 63 ft. deep above the rock. When the caisson had fairly entered the sand a deposit was made rapidly around it, especially in the eddy created below the caisson. The sides of the caisson were swept to some extent by the current, otherwise the derrick boats on each side of it would have grounded on the deposit. This deposit was increased by the discharge from the sand pumps, and by the completion of the ice-breaker above the pier, so that for 20 or 30 days before it reached the rock, the sand was visible above the water, both above and below the caisson. The iron walls of the caisson had consequently a severe external pressure upon them from this mass of sand, and as the sides of the pier were inclined whilst the walls of the caisson were vertical, a space was left between the two. This space was at first occupied with bracings against the masonry to sustain the walls. As the pier descended and the pressure increased, sand from the pumps was discharged into it, and in this way the walls were relieved; the height of sand inside, between the caisson walls and the pier, being maintained at the level of the sand on the outside. The design was to keep the masonry constantly built up above water as the pier descended. The failure of the granite company to

deliver in time the granite which was intended to form the exterior of the pier above low-water mark, prevented me from following out this design. At the time the granite was wanted, the river was from ten to twelve feet above low-water mark, and there was left only the alternative of stopping the descent of the caisson that much above the bed-rock and awaiting the receipt of the granite, or else allowing the pier to descend and trust to the walls of the caisson to exclude the water above the top of the pier. Three courses of granite, each 2 ft. thick, were received in time, but when the pier reached the bed-rock the top of the masonry was about 6 ft. below the surface of the water.

To prevent danger to the workmen in the air-chamber, in the event of the walls of the caisson giving way under a pressure of water, a condition of things deemed possible, but not expected, the shafts or wells through the masonry, by which access was obtained to the air-locks which were at the bottom of the pier, were kept securely built up above the level of the water. On one or two occasions leaks occurred in the caisson walls, causing the top of the masonry to be flooded ; but this precaution prevented a suspension ot the work of filling the air-chamber under the pier with concrete, in consequence of such accidents, as the shafts remained free of water. During the month of April, however, the river rose to within 9 ft. 6 in. of the City Directrix, and was 19 ft. 6 in. above the top of the masonry. From the moment the caisson touched the rock up to this time, the filling of the air-chamber with concrete had been progressing almost without interruption. When the water reached this point, the walls of the caisson suddenly sprung a leak, and the pier was again flooded in a few moments. As the flooding of the pier usually increased the leakage in the shafts very much, it was not found practicable to continue work in the air-chamber when it happened, if the depth over the pier exceeded a few feet. When this accident occurred, the men were immediately signalled to come up from the air-chamber, then 110½ ft. below the surface of the river. This they did with entire safety. A suspension of work on the pier was then ordered until the water should subside.

Examinations of the caisson walls were made by our diver, Capt. Quigley, and careful soundings were made to ascertain the depth of the sand on the inside and outside of the caisson. It was then discovered that 55 ft. in depth of the sand on the east side of the caisson (on the outer side) had been scoured away by the action of the current, the soundings showing but 35 ft. of sand remaining above the bed-rock. This had reversed the strains on the caisson walls ; the corresponding 55 ft. of sand on the inside between the pier and the caisson, had by its gravity burst out the eastern wall of the caisson, now no longer supported by the sand on the outside. This wall was of plate iron $\frac{3}{8}$ of an inch in thickness. This rupture renderd the further use of the caisson as a coffer-dam, forever after totally impracticable. The upper portion of it was consequently removed, and in its stead there was secured around the pier a wooden dam, joined together in sections corresponding to the sides and ends of the pier, and having a large cushion near its lower edge, on the inner side, to fit against the fourth joint of the masonry below the top course of the pier. This work was admirably executed under the direction of the Superintendent of Construction, Mr. W. K. McComas ; the submarine work being very skilfully performed by Capt. Quigley. On the 13th of August the water was again pumped off from the top of the masonry. Since this time the pier has been carried up to the height of 117 ft. above the bed-rock on which it rests, and is now (October 1st) 19 ft. 9 in. above the present level of the river surface. The coffer-dam has been removed from around it, and no apprehension of further trouble from water during its completion need be entertained. It measures at its base, in the direction of the current, 82 ft. in length, and transversely 60 ft., and on the top at its present height, 75 ft. 7 in. by 35 ft. 1 in. It now contains 13,240 cubic yards of masonry, concrete, and brick work. The vertical wells or shafts through it, were lined with brickwork from 13 to 22 in. in thickness. These openings were carefully filled up with concrete and the entire pier is now one solid mass of masonry.

In addition to the almost constant presence of the Superintendent of Construction, in charge of all the works, it was

made the duty of three civil engineers, familiar with the plans, machinery, etc., to give their personal superintendence to the sinking of the pier; one being constantly on duty, watching the progress of the work, and keeping a record of everything of interest occurring. The necessary number of steam engineers, machinists and firemen, were employed for keeping the engines at work night and day, and the machinery in perfect order, so that the work could go on without any interruption whatever. To accomplish this desirable object, sufficient duplicate pumps, engines, boilers, etc., were provided, so that the failure of any one piece of the machinery would cause no stoppage in the progress of the work. The pier was placed on the rock in 126 days after the laying of the first stone, which period included the most inhospitable season of the year. The mason work was suspended during 20 days of this time on account of bad weather. During 15 days it was impossible to tow a barge of stone to the pier on account of the running ice.

TELEGRAPH.

When this pier had reached the depth of 66 feet, a telegraphic instrument was placed in the air-chamber, and a wire was led to the office of the Superintendent of Construction on one of the derrick boats at the pier, and also to the office of the Chief Engineer in the city. By this means messages were transmitted to and from the air-chamber, and between the offices of the Superintendent of Construction and that of the Chief Engineer, by which I was, when not present, regularly advised of the progress and condition of the work during the sinking of the pier. The knowledge that a means of communication with the upper world was constantly at hand in the air-chamber, and one which was not likely to be interrupted by any accident endangering the lives of the workmen in it, was productive of a very salutary moral effect upon them.

These telegraphic arrangements were courteously put up complete under the gratuitous superintendence of Col. Chas. H. Haskins, General Superintendent of the Pacific and Atlantic Telegraph Company. The instruments were of the kind known as "alphabetical," and were easily understood and operated by those placed in charge of them in the service of the Bridge Company.

FILLING THE AIR-CHAMBER.

The filling of the air-chamber was executed in the most careful and substantial manner under the immediate direction of the Superintendent of Construction. The preparation and disposition of the concrete were made in the air-chamber (from 103 to 110½ ft. beneath the surface of the river), under the immediate supervision of Mr. Rud. Wieser, C. E., Chief Inspector of Masonry, and his assistants, Mr. Rich. Richardson and Mr. Fritz Eberley, master masons, one or the other being constantly on duty. From frequent personal inspection, I am warranted in saying that this part of the work is unsurpassed in excellence by that of any part of the masonry above water.

The filling of the air-chamber with concrete commenced on the 2d day of last March, and was finished on the 27th of last May. The working time being 53 days. The space filled may be fairly stated at nearly 36,000 cubic ft. The area of the base of the pier is 4,020 sq. ft. and the height of the chamber 9 ft. The caisson was stopped as soon as it touched the bed-rock. This was at its southwest corner. At the northwest corner its edge was 8 in. from the rock. The northeast corner was 16 in. and the southeast 8 in. It will be seen from this that the rock was, fortunately, very nearly level. The sand beneath the edge of the caisson was removed, the rock laid bare and the space filled carefully with concrete, the air pressure being sufficient to prevent a more rapid infiltration of the water under the edge of the caisson than could be managed by the pumping arrangements within it. The sand seemed packed so firmly that no trouble was taken to barricade it out of this space between the rock and the edge of the caisson. When the entire edge of the caisson and the space under its two great girders were thus concreted, the rock in its interior was gradually cleared of sand and the concrete placed directly upon it in layers of 9 or 10 in. in thickness, the closing courses under the roof of the chamber being stoutly rammed in place. The air-locks were then filled with the same material, and finally the shafts. The concrete was made

of broken limestone thoroughly washed, the interstices being filled with mortar made of equal parts of Akron cement and pure sand.

During the sinking of the pier the sand pumps designed by me for this special purpose, gave great satisfaction and proved entirely successful. One pump of $3\frac{1}{2}$ inches bore was found quite capable of raising 20 cubic yards of sand 120 ft. high per hour; the water pressure required to supply the jet being about 150 lbs. per sq. in.

PRESSURE IN THE AIR-CHAMBER.

The pressure of air in the air-chamber was very accurately determined by the depth of the caisson below the surface. Any greater pressure than that due to the depth, caused the air to escape beneath it, but when the caisson had penetrated into the sand to a considerable distance, it was discovered that the water level formed by the air under or across the bottom of the chamber was nearly a foot lower than the bottom edge of the caisson. When the caison was but a few feet in the sand, the air forced its way up by its sides in one or two currents of large volume, but as it penetrated more deeply, the passage of the air through the sand evidently became more difficult, and it appeared in small bubbles 60 or 70 ft. distant from the caisson. This retardation of the escapement of the air from beneath the caisson, caused an increase of air pressure by which the water was held at a greater or lesser depth below the line of the bottom of the air-chamber. The sand inclosed in the air-chamber and forming its floor was usually 1 or 2 ft. more elevated than the lower edge of the chamber, and was entirely devoid of water, the air pressure expelling the water from it down below the edge of the caisson as just stated. The distance to which it was thus expelled and maintained, was at no time discovered to exceed 10 in., and generally it was not over 8 in. This would give an air pressure equal to nearly 1 ft. more than the depth of the caisson, or about $\frac{1}{3}$ of a pound per square inch more. This difficulty of escapement of the air through the sand was increased somewhat by concreting under the edge of the caisson on the rock, and the actual air pressure could then be no longer accurately determined by the height of the water above. The pressure gauges usually indicated a pressure of 1 or 2 lbs. more than the depth of water would give by calculation. This was caused in a great measure, however, by the friction of the air in the pipes, the gauges being at the pumps and not in the air-chamber. A column of water 110 ft. 6 in. in height would be equal to a pressure of 47.96 lbs. per square inch, assuming the weight of the water to be 62.5 lbs. per cubic foot. The greatest pressure marked by the gauges was 52 lbs., and it is not probable that the pressure in the air-chamber ever exceeded 50 or 51 lbs.

EFFECTS OF COMPRESSED AIR ON THE MEN.

The first symptom manifesting itself, caused by the pressure of the air, is painfulness in one or both ears. The Eustachian tubes, extending from the back of the mouth to the bony cavities over which the drums of the ears are distended, are so minute as not to allow the compressed air to pass rapidly through them to these cavities, and when the pressure is increased rapidly, the external pressure on the drums causes pain. These tubes constitute a provision of nature to relieve the ears of such barometric changes as occur in the atmosphere in which we live. The act of swallowing facilitates the passage of the air through them, and thus equalizes the pressure on both sides of the drums, and prevents the pain. The pressure may be admitted into the air-lock so rapidly that this natural remedy will not in all cases relieve it. By closing the nostrils between the thumb and fingers, shutting the lips tightly and inflating the cheeks, the Eustachian tubes are opened and the pressure on the inner and outer surfaces of the tympanum is equalized, and the pain prevented. This method must be used and repeated from time to time as the pressure is let on, if it be increased rapidly. No inconvenience is felt by the reaction when the pressure is let off, as the compressed air within the drums has a tendency to open the tubes, and thus facilitates its escape through them; whereas increasing the pressure has the effect of collapsing them, and therefore makes it more difficult to admit the compressed air within the cavities of the ears. It frequently occurs, however, from some abnormal condition of these tubes, as when inflamed by a cold in the head, that neither of these remedies will relieve the pain.

To continue the admission of compressed air into the lock, under such circumstances, would intensify the suffering, and possibly rupture the tympanum, therefore the lock tenders were particularly instructed to shut off the compressed air at the moment any one in the lock experienced pain about the ears; and then, if it could not be relieved by the above means, the lock was opened and the person was not permitted to go through into the air-chamber. Sometimes 15 min. were occupied in passing persons through the first time, after which they usually had no further trouble from this cause.

The fact that the depth penetrated by the air-chamber was considerably greater than that hitherto reached in any similar work, left me without any benefit from the experience of others, in either guarding against any injurious effects of this great pressure upon the workmen and engineers subjected to it, or of availing myself of any known specific for relieving those affected by it. When the depth of 60 ft. had been attained, some few of the workmen were affected by a muscular paralysis of the lower limbs. This was rarely accompanied with pain, and usually passed off in the course of a day or two. As the penetration of the pier progressed, the paralysis became more difficult to subdue. In some cases the arms were involved, and in a few cases the sphincter muscles and bowels. The patients also suffered much pain in the joints when the symptoms were severe. An average of at least 9 out of 10 of those affected, suffered no pain whatever, but soon recovered, and generally returned to the work.

The duration of the watches in the air-chamber was gradually shortened from 4 hrs. to 3, and then to 2, and finally to 1 hr.

The use of galvanic bands or armor seemed, in the opinion of the Superintendent of Construction, the foreman of the chamber, and the men, to give remarkable immunity from these attacks. They were all ultimately provided with them. These bands were made of alternate scales of zinc and silver, and were worn around the wrists, arms, ankles and waist, and also under the soles of the feet. Sufficient moisture and acidity were supplied by the perspiration to establish galvanic action in the armor, and as the opinion among those most accustomed to the chamber was almost unanimous in favor of this remedy, I am very much inclined to believe it valuable.

Immediately on the manifestation of greater severity in the symptoms, a hospital boat was fitted up at the pier, and one of the ablest physicians in the city (Dr. A. Jaminet) was engaged to attend those affected, and also to institute such sanitary measures as his judgment should dictate. A careful examination of the health and bodily condition of every workman was daily made, and none were permitted to engage in the work without the approval of Dr. Jaminet. Those most severely affected were sent to the City Hospital and had the benefit of the advice and treatment of its resident physician, Prof. E. A. Clark. The total number of men employed in the air-chamber of this pier was 352. Of this number about 30 were seriously affected. Notwithstanding the care and skill with which those most severely attacked were treated, 12 of the cases proved fatal. Each one of these, without exception I believe, was made the subject of careful inquest by the coroner, aided by an autopsy conducted usually by some of our most skilful surgeons and physicians. Whilst the exciting cause in all of these cases was doubtless the exposure of the system to the pressure of the condensed air of the chamber, the habits and condition of several of those who died were at the time they went to work, such as would have excluded them from it if subjected to the examination of Dr. Jaminet, and the verdict in about one-half of the cases gave a totally different cause for the death of the patient. Nearly or quite all of these deaths happened to men unaccustomed to the work; several of them to men who had worked but one watch of 2 hrs. In contrast to this, is the fact that quite a large number of the men (certainly one-half of those constantly employed) commenced with the work at its inception and remained throughout its continuance entirely without injury or inconvenience.

The gentlemen composing the engineer corps of the bridge all visited the air-chamber, some of them quite often, either in the discharge of their professional duties, or from motives of curiosity, and none of them suffered any injury whatever.

Much diversity of opinion was expres-

sed by the medical gentlemen who investigated the symptoms and held autopsies of the deceased. Some of these gentlemen maintained that a slower transition from the abnormal to the natural pressure would have been less injurious; others claimed, on the contrary, that it was from the too rapid application of pressure in passing from the natural into the compressed air. The fact that the air-lock tenders were in no case affected, although subjected many times during a watch of 2 hrs. in the air-lock to rapidly alternating conditions of the atmosphere, at one moment in its normal state in the lock, and five minutes later exerting a pressure of 50 lbs. per sq. in. upon every part of the body, would seem to prove both of these theories unsound, and lead us to believe that in the length of time to which the human system is subjected to this extraordinary pressure, exists the real source of danger, and not from any rapid alternations of pressure to which it is exposed. After the caisson reached the rock, I have frequently, when passing through the air-lock, admitted the compressed air into it so quickly that none but those well accustomed to it could relieve the pressure upon their ears, and yet I felt no ill effects whatever from this rapidly increased pressure; and, in going out, I have let the pressure off so fast that the temperature in the lock has fallen 32 deg. (Fahr.) in consequence. These transitions occupied but 3 or 4 min.

The fact that the air-chamber was briefly visited by thousands of persons, including many delicate ladies, even after it had reached the bed-rock—some remaining as long as an hour in it without any of them experiencing the slightest ill effects from the pressure—and the fact that no cases of any importance whatever occurred among the workmen after the watches were reduced to 1 hr., satisfies me that this is the true cause of the paralysis, and that by lessening still more the duration of the watches, a depth considerably greater can be reached without injury to the workmen. Too long a continuance in the air-chamber was almost invariably followed by symptoms of exhaustion and paralysis. Dr. Jaminet, on one occasion, remained $2\frac{3}{4}$ hrs. when the depth was over 90 ft., and was dangerously attacked soon after reaching home.

Symptoms of paralysis rarely occurred in the shaft, but generally after the stairs were ascended, and never in the air-lock or air-chamber.

A large amount of money has been gratuitously expended by the Company in assisting and providing for those who were seriously affected, and in relieving the wants of their families during their illness.

As a merited recognition of the courage, fidelity, and services of the men employed in the air-chamber of the East Pier, and as an evidence of my personal appreciation of their faithfulness and good conduct, I have placed in the appendix to this report, the names of those engaged in the work when the pier reached the rock.

THE WEST PIER.

The sinking of the West Pier began on the 15th day of January of last year, that being the day on which the first stone was laid on the caisson. As it was commenced 12 weeks later than the East Pier, advantage could be taken of the experience gained in sinking the latter. On the East Pier the interruption and annoyance caused by the necessity of riveting on the iron plates outside of the masonry, to exclude the water as the pier descended, led me to devise some means whereby this inconvenience might be prevented, and the cost of the iron saved. The design of the West caisson was so modified that the use of these plates could be abandoned, after the first 29 ft.; 9 ft. of this height being the air-chamber, and the remaining 20 ft. enveloping the masonry above the chamber. This height of plate iron was deemed requisite to give such rigidity to the caisson as would insure it against any twisting or straining that would endanger the bond of the masonry. After a depth of 40 or 50 ft. was reached by the East Pier, it was found evident that brick linings in the shafts, although surrounded by many feet of masonry, carefully laid in hydraulic cement, were not sufficient to exclude the water, which, at this depth, filtered through quite rapidly. To prevent this, and to enable the iron around the outside of the pier to be dispensed with on the West Pier, its shafts were lined with white pine staves, 3 in. thick in the centre shaft, which was 10 ft. in diameter, and $2\frac{1}{2}$ in. thick in the smaller wells, which were 4

ft. 9 in. in diameter. This device answered admirably, and the estimated saving in plate iron, over the original design, was about $10,000. The lower staves were, however, found to be too weak to sustain the high water of the Spring freshet, without expansion bands of 1x3 in. bar iron, which were placed against them in the shafts in time to avoid any disaster. This novel feature of wooden linings, and no exterior envelope for the masonry, will be introduced in the East abutment. The caisson for it is, however, made so strong, that the iron will only be brought up to a height of 12 ft. around the base of the masonry. The lining staves in its wells will be so much stronger, that they will require no internal supporting rings of iron.

Nothing could have exceeded the perfect working of these economic improvements in sinking the West Pier had not the contractors failed to deliver the granite for it in time. When the point was reached at which the granite became necessary, the surface of the masonry was 6 or 8 ft. above water and the base of the pier 18 or 20 ft. from the rock. A judicious view of the case, having reference solely to the cost of constructing this pier, would have dictated a suspension of the work until the stone should have arrived, rather than continue the sinking of the pier and suffer the top of the masonry to descend below the surface of the water. Other questions however, were involved of a more serious nature. It was universally conceded that any effort to negotiate the securities of the Company would be fruitless unless preceded by an absolute demonstration of the practicability of putting down the channel piers of your bridge upon the bed rock of the Mississippi, through the unusual depths of water and sand that were to be encountered. The East Pier was in a similar condition at this time, and there remained no alternative but to continue sinking both, to do which it was necessary to build up and brace out the iron plates which had been carried up from the air-chamber around the masonry of the last pier, and thus dam out the water from covering the top of the masonry as it descended below the surface of the Mississippi, so as to be able to resume the laying of stone when the granite should arrive ; and as the West Pier was without any such iron envelope, it became necessary to attach the wooden walls of a coffer-dam to its sides in such a manner as to exclude the water from the top of the pier. This was done by padding the lower edge of the dam and attaching its sides securely to the masonry, several courses below the top. This answered very well until the last 9 inches of this pier was sunk to the rock. Some of the bolts holding down the dam at the south end of the pier gave way, and the friction of the sand, then 14 ft. high on the outside of the dam and nearly to the surface of the water, prevented the settlement of the dam with the pier at this particular point. Two outside courses of the limestone to which it was attached were held up by the dam nearly across the entire end of the pier. This mishap made it necessary to pump away the sand outside this end of the dam, and put down a large pad or wooden covering reaching below the two disturbed courses, then pump out the dam and relay them. This was done at a depth of about 17 ft. below the surface. The dam was not pumped out till the granite arrived, as the water over the pier did not prevent the work in the chamber, access to it being obtained through the wooden shafts or wells which passed down through the water that was over the masonry. This unexpected trouble, and that at the east pier, were caused solely by the failure of the Richmond Granite Co. to deliver the granite in time. Its delivery was due several months before it was needed, and yet it was not delivered until several months after it was wanted. The loss to your Company, resulting from this failure, I estimate to amount to at least $50,000.

THE EAST ABUTMENT PIER.

The complete success which attended the sinking of the East Pier convinced me of the practicability of sinking the east abutment pier to the rock in the same manner. The original plans of the bridge did not contemplate resting this abutment on the rock. It was beheved quite practicable to protect its foundation with riprap stone, and to secure stability and safety by resting it on piles, which were to have been driven to a distance of 50 ft. below low-water mark. When the Directory of the Company were assured of the practicability of resting this abutment upon the bed-rock itself, and of thus terminating

for ever all doubts as to the absolute stability of each one of the four great piers of your bridge, the desire that this, the largest of them all, should be placed on the rock also, was unanimous; although the excess in cost involved over that of the original design was understood to be about $175,000. No less than 10,000 additional cubic yards of masonry *below* the line of the tops of the piling on which it was originally intended to start the masonry, are required to sink the pier to the rock. Consequently below this line, it will require nearly as much masonry as will be contained in the west abutment when the latter is completed.

This abutment, when completed, will contain 22,453 cubic yards of masonry, including concrete and brick-work, and will measure in height, from the rock to the top of its cornice, 196 ft. 9 in.

The depth of the rock at the site of the abutment was ascertained by careful borings to be 8 ft. lower than that at the East Pier, or 136 ft. below high water mark.

It is not probable that we shall have to contend with much deeper water or much greater air pressure than that encountered in sinking the East Pier. The bed-rock at this abutment is 94 ft. below extreme low-water mark, and the river is not likely to be more than 18 ft. above that during the seasons occupied in sinking the pier. Extreme low-water mark is only reached when the river is gorged with ice above the city, and the volume of water below the gorge becomes in consequence greatly lessened. The ordinary low water rarely reaches a point within five feet of low-water mark.

In accordance with the wish of the Directory, preparations for sinking this abutment to the rock were commenced, and are now nearly completed. The caisson is nearly ready for launching, after which it will be immediately towed into position, and be made ready for sinking. It will cover when on the rock, 5,000 sq. ft. of surface, and is therefore about one quarter larger than the base of the East Pier. A large trestle work has been erected immediately east of the site of this abutment, extending a few feet above high water mark, on which is being placed a portion of the necessary machinera for sinking the caisson. This trestle-work was rendered necessary because of the shallowness of the water on that side of the abutment. On the west side of the caisson one of the derrick boats used at the East Pier will be located, and on the trestle-work will be placed much of the machinery of the other derrick boat, which was used on the other side of the East Pier.

THE EAST ABUTMENT CAISSON.

This caisson will have several novel features in its construction, which I think will make it superior to those used for the East and West Piers. The main shaft will have at the bottom 2 air-locks, each 8 ft. in diameter, instead of one of but 6 ft. The main shaft will be carried down into the air chamber 10 ft. in diameter, instead of but 5 ft.

The East Pier caisson had 6 other shafts of 4 ft. 9 in. in diameter, with air-locks of the same diameter at the bottom of each. This caisson will have but 2 other shafts of 4 ft. in diameter, with an air-lock at the bottom of each, 8 ft. in diameter. These last 2 shafts are enlarged below the roof of the air-chamber to 8 ft. in diameter each. The increased diameter of the locks will contribute to the health of the men, as it is sometimes necessary for 12 or 14 of them to be in one of them at the same time, for several minutes, until the pressures are equalized. As all 4 of these locks are within the air chamber, and also the lower ends of the 3 shafts, and as about 1,800 cubic ft. of space is occupied by them, there will be that much less space to fill in the compressed air when the pier is down.

The centre shaft alone will be used for the workmen, unless some unforeseen accident should render it necessary for them to use one or the other of the side shafts, which are provided almost solely for safety. The extra size of the locks makes either one of them capable of holding in an emergency all the men that will be in the air-chamber at one time, and hence their security will be increased.

To avoid the labor of walking up a circular stairway about 120 ft. high after leaving the air-chamber, the main shaft, in addition to the stairway, will have an elevator, or lift, to bring the men up. This, it is believed, will contribute greatly to their health. When they are at work in a pressure of 45 or 50 lbs. above that of the natural atmosphere, there ensues a rapid exhaustion of the physical ener-

gies. When relieved from duty, a considerable degree of prostration is frequently manifested, and the foremen of the different gangs were in consequence instructed by the physician to cause the men to ascend the stairs leisurely, to avoid increasing it. I confidently believe, therefore, that by bringing the men to the surface in the elevator, there will be much less danger of injury occurring from their employment in the air-chamber.

LIGHTING THE CAISSON.

A different method of lighting the air-chamber will likewise be adopted. In the other caissons much inconvenience was experienced on account of the particles of unburned carbon thrown off from the flames of the candles used. The consumption of the candles under the action of the compressed air was much more rapid than in the normal atmosphere. At the depth of 100 ft., they were found to be consumed in about $\frac{3}{5}$ of the time required in the open air. Large quantities of smoke were emitted from the flames, and the air was filled with particles of floating carbon, which could only be removed thoroughly by placing a rose jet on the nozzle of a water hose in the chamber, and discharging the spray in every direction. Some amelioration of the evil was obtained by burning the candles under an inverted funnel or chimney, communicating with one of the shafts by a small outlet pipe, through which the escape of the compressed air was regulated by a cock, thus creating a draft above the flame by which the smoke was carried off.

The calcium light would probably prove the most satisfactory one which could be employed in the chamber, were it not for the excessive cost of it in this city. For the 150 days which will be required in sinking this pier and completing its foundation on the rock, the cost of lighting the three compartments of the chamber with calcium lights, would be at least $5,000. By the means devised for the purpose, the cost cannot exceed one-fifth of that sum.

The difficulty of extinguishing a flame in an atmosphere of such density, caused me to forbid the use of oil lamps in the chamber before a depth of 80 ft. had been reached. The clothing of two of the men having taken fire from contact with some of the hand lamps or candles used in the caisson, it was found exceedingly difficult to extinguish the flames. One of them was severely burned, although his garments were almost entirely woolen. It was deemed unsafe to risk the danger of having the clothing of the men saturated with oil from the accidental breaking of a lamp which might, by the same casualty, ignite their garments and thus endanger their lives. The use of oil was therefore forbidden.

At the depth of 80 ft. it was found that the flame of a candle would immediately return to the wick after being blown out with the breath. At the depth of 108½ ft. below the surface of the river, I blew out the flame of one of them thirteen consecutive times in the course of half a minute, and each time, excepting the last, it returned to its wick. Almost as long as a small portion of the wick remained incandescent, the flame would return, and when the glowing particle of two separate candles failed to possess sufficient heat to restore the flame to either, it would reappear at once by placing the luminous portions of the two wicks in contact.

The chamber of this caisson will be lighted by candles contained within glass globes of similar construction to those used in lighting railway carriages. The glass will be of strength sufficient to sustain the external pressure of the condensed air. The chimney will consist of an outlet pipe of 1 in. diameter, communicating with one of the shafts, and the compressed air will only be admitted within the globe in which the candle is placed, through a small regulating valve. The candle will therefore be burning under the normal pressure of air. A stopcock in the chimney will prevent the escape of air from the chamber through the globe, when it is desirable to put in another candle, or to clean the glass.

TIMBER WORK.

Beneath the masonry piers of suspension and truss bridges, it is quite common to employ a considerable amount of timber. Where the pressure upon the pier is a vertical one, this economical substitute for stone is admissible, but in the piers of an arched bridge, where some one span is at times loaded while the others are unloaded, the thrust of the loaded arch has a tendency to oscillate the piers,

and with a few feet in thickness of a material so elastic as wood under their bases, this oscillation would prove a dangerous feature. In the abutment piers where the thrust is only from one side, and oscillation is prevented by the works on shore, timber may be safely used to a considerable extent. To give the desired stiffness to the caisson for this abutment and avoid the more costly use of iron, the roof of the air-chamber is made of timber 4 ft. and 10 in. in thickness. A large amount of timber is also used in constructing and stiffening the sides of the air-chamber, which are 10 ft. high, and in forming two horizontal trusses or girders through the air-chamber. These two girders are each 10 ft. thick at the top, $3\frac{1}{2}$ ft. at the base and 9 ft. in height. They are about 73 ft. long and are interlocked at each end with the sides of the air-chamber. They divide this chamber into three nearly equal compartments in the direction of the length of the bridge. Communication is made between these compartments by means of two openings through each girder.

The sides of the chamber are $8\frac{1}{2}$ ft. thick at the top and 18 in. at the bottom, and are composed of timbers, some placed vertically, others horizontally, and some inclined at an angle of about 45 deg., and the whole, including roof and girders, thoroughly interlocked together, and bolted with large iron bolts. All of the timber is of the very best white oak, and was squared up with two steam planers belonging to the Company. In addition to the iron bolting used, these timbers are thoroughly secured together with large white oak tree-nails.

The wood work of the caisson has been most admirably executed under the superintendence of Mr. John Dunlap, master of ship-carpenters.

PLATE IRON WORK.

Enveloping this entire wooden structure is an iron covering riveted together to prevent the escape of the air which is to supply the workmen. This is of $\frac{3}{8}$ in. plate iron, and its sides are increased in thickness at the bottom edge to three in., by riveting 4 $\frac{3}{4}$ in. plates together. These extend several ft. up the sides. This iron edge extends 10 in. down below the wooden sides and forms the cutting edge of the caisson. Every 2 ft. the iron sides are strengthened by vertical angle irons 3 by 7 in. in size, riveted on flatwise on the outside of the caisson. Through these angle bars, bolts $1\frac{1}{2}$ in. in diameter are inserted, and by them the iron and wooden sides are strongly held together. This iron covering extends over the wooden top of the air-chamber and forms a floor on which the masonry will be laid. The 3 shafts passing through this floor, by which access to the chamber is obtained are tightly riveted to it.

The iron sides are carried up 12 ft. above this floor, where they will terminate. The masonry above this point will therefore have no exterior envelope such as the East Pier had.

Nearly all the iron used in this envelope was obtained from the hull of the iron gun-boat Milwaukie, the wreck of which was purchased about 18 months ago. This iron work has been executed by Capt. Wm. S. Nelson, the skilful and energetic contractor who built the caissons of the two channel piers.

WATER-TIGHT LININGS.

The water penetrating the masonry will be excluded from the 3 shafts by white pine linings, arranged like the staves of a cask. The staves composing this lining in the main well or shaft, which is 10 ft. in diameter, will be 10 in. thick in the lower part, and will be gradually diminished to 3 in. at the top. In sinking the pier, the top of the masonry and shafts, will be kept constantly built up above the surface of the river.

FILLING THE AIR-CHAMBER.

The most valuable improvement in the design of the caisson will I think, be found in the method devised for filling the chamber when it has reached the rock. It is a well established fact that sand constitutes one of the most reliable and durable materials for foundations known, if availed of in positions where it can be securely retained under the structure erected upon it. It is an equally well-established fact that timber when entirely submerged in fresh water foundations, is indestructible. These two facts will be relied upon in filling the air-chamber and fixing the foundation of this pier upon the rock. Instead of concrete, sand will be chiefly used for filling the chamber. The sides of

the caisson are of great thickness, and are thoroughly interlocked at the corners of the air-chamber, and at the ends of the girders. The possibility of the sand surrounding the pier ever being scoured out to the rock, at the site of this abutment, is a very remote one. It is certainly much more improbable than that it may be scoured thus deeply at the sites of the two channel piers. To avoid all danger from this very remote possibility throughout all time, whatever space there may be existing between the timber walls of the caisson and the bed-rock, after the caisson shall have reached it, will be thoroughly concreted, so that these walls will have a substantial bearing upon a solid material which cannot be affected by any current that may possibly wash the base of the pier. The walls of the air-chamber are so framed as to be sufficiently strong to resist the bursting pressure of the sand within the chamber, caused by the weight of the masonry of the pier and half the side span upon it, even after all the iron used in it shall have been corroded away. The base of the pier is 5,000 sq. ft. in area, and the weight of the entire pier including $\frac{1}{2}$ of the span, will be about 46,500 tons. The pressure per sq. ft. on the rock would, therefore, be 18,600 lbs. The area of the wooden edge of the caisson, including that of the bottom of the girders, air-locks and shafts, is about 1,250 sq. ft. This area alone would be capable of sustaining the pier, without any additional support from the sand contained within the air-chamber. Without this sand filling, the pressure upon the wooden base of the caisson (including the locks and shafts) would be about 74,000 lbs. per sq. ft. or 514 lbs. per sq. in. This pressure is not beyond the power of good white oak to resist, nor would it be sufficient to crush the concrete that will be used in filling the small space between the oak and the rock.

Tests made with our testing machine upon a number of blocks of concrete only six weeks old, gave an average resistance to crushing, equal to 1,200 lbs. per sq. in. Of course, with the integrity of the exterior of the caisson unimpaired, the escape of sand from the interior would be impossible. With the interior compactly filled, the pressure of the superincumbent mass must necessarily be very nearly equally distributed over every part of the caisson, and hence it cannot exceed about 18,600 lbs. per sq. ft.

The tedious process used in concreting the air-chamber of the channel piers, together with the objections to working men at such great depths, induced me to devise some method by which a smaller amount of manual labor could be made to accomplish equally good results. By the plan determined on in this case, I confidently hope to accomplish the necessary work in the air-chamber with a 5th or 6th of the manual labor which was required under the East Pier.

This method is so simple as to be readily explained. So soon as the rock shall have been struck by the iron edge of the caisson, the space then remaining between the wooden walls of the caisson and the rock, will be thoroughly concreted. The sand under the two girders will be left intact. The borings indicate that the rock is quite level, and it is not probable that inequalities of more than 18 in. will be found in it. It is estimated that 100 cubic yds. of concrete will be sufficient to support these walls, forming a bed of an average width of 3 ft. 6 in., by 2 ft. 6 in. in height. This concreting being done, all the pipes passing vertically through various parts of the pier, and used for air, water, and sand-pumps, will be closed at the top, and the pumps, valves, and pipes connected with them in the air-chamber, will then be taken off. There will be 19 of these vertical pipes, each either 4 or 6 in. in diameter, the lower ends of which will be enlarged conically through 5 ft. of their lengths. These pipes being opened at their lower extremities, and one of the inner doors of an air-lock being secured from being clogged by sand, the air from the chamber will be permitted to escape, and the chamber will be filled with water. This being done, sand will be introduced through the various vertical pipes mentioned. By means of plummets in these pipes, we shall be able to determine the height of the sand discharged in them, and when it is near the roof of the chamber, the air will be again pumped in, and workmen will be sent in to level it off. By repeating this process two or three times, the chamber can be filled nearly to the roof with sand compacted in the water, which will insure its solidity. The remaining space can then be filled with

concrete, rammed in under the roof of the chamber. The great thickness of the walls, and of the girders, where they join the roof, reduces the area of the upper part of the chamber very greatly. The upper 3 ft. of it measures only 2,025 cub. ft. in area, exclusive of the air-locks and shafts.

To fill the air-chamber of the East Pier, required 1,340 cub. yards of concrete, which was placed in position by manual labor, under an air pressure of nearly 50 lbs. per sq. in. Ths pier is 25 per cent. larger, and will require only about 200 yards of concrete to be placed in it under similar conditions; hence the work required to be done in this chamber will be greatly less than in that of the East Pier.

MUTUAL PRESSURE OF LIQUIDS AND SOLIDS.

Translated from "Exposé de la Situation de la Mecanique Appliquée."

That division of hydraulics which considers the mutual reactions of solids and liquids in relative motion has made small progress. Theory yields to observation, and empirical formulas. Yet the fundamental problem of determining the normal pressure of a liquid vein spreading over an indefinite plane, has been rigorously solved. The theorem of projected quantities of motion, gives the sum of the normal actions of the plane upon the vein, and shows that it is composed of two parts; one representing what may be called the static pressure of the water, is due to the component of weight taken perpendicular to the plane; the other is the dynamic pressure, and is expressed by a term containing as factor the square of the velocity of the current. It is seen that the pressure would be less if the plane, instead of being indefinite, allowed the liquid filaments to escape in the direction of their primitive motion; and that it would be greater, if instead of the plane there should be substituted a concave surface reflecting the filaments into an opposite direction.

This problem of impact of a stream against a plane being solved, attempts are made to refer to it analogous practical problems, in which we have to consider the action of a liquid current impinging upon a body of any form.

The earliest experiments in the reactions of water and bodies immersed in it were those of Dubuat. This celebrated hydraulic engineer caused planes and solids of various forms and dimensions to move in still water, and determined in each case the co-efficient with which to multiply the product of the transverse section and the square of the velocity, in order to obtain the measure of resistance. If the solid has a prismatic form, the phenomena are made more complex by the friction along the lateral faces. Tapering towards the extremities reduces the value of the co-efficient of resistance. Long experience in navigation has determined the most advantageous forms for the keel of a ship.

In canals resistance to traction depends not only on velocity and section of boat, but also upon the section of the canal; traction being more difficult, with equal section, upon a narrow, than upon a wide canal. It has been found that beyond a certain velocity traction decreases rapidly. This velocity is that of the motion of the wave caused by the floating body upon the surface of the water. This was profitably applied in the Canal de Ourcq, between Meaux and Paris, in running the boats carrying the mail. Such a velocity is not practicable with freight boats.

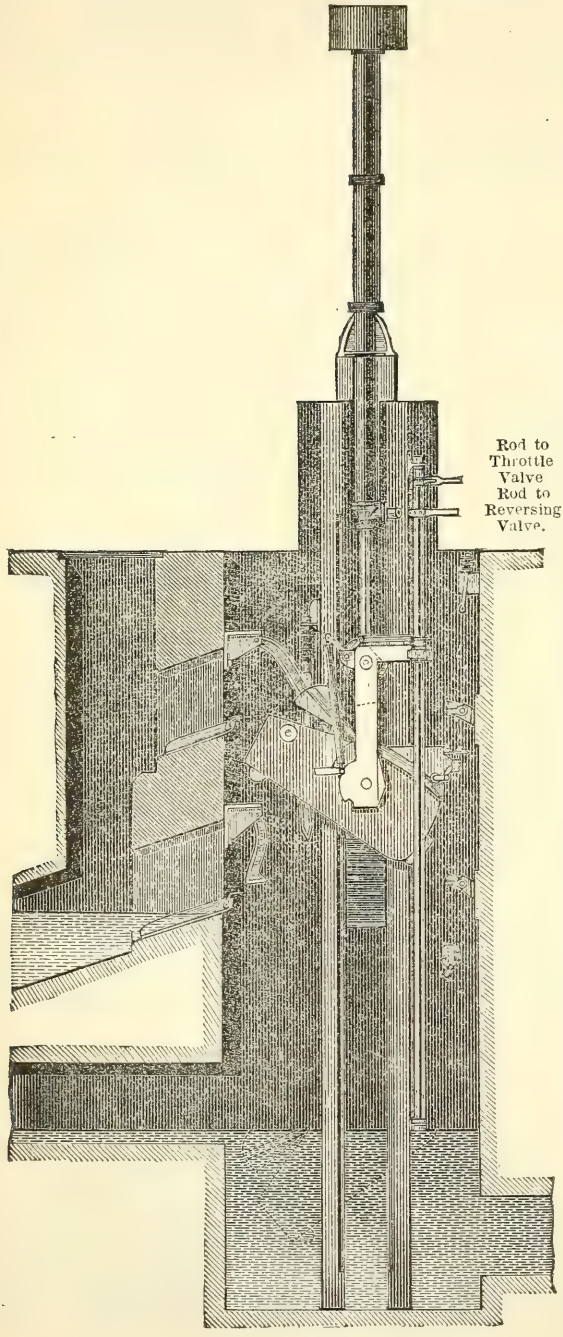
Dubuat made experiments of two kinds; in one he placed the solid body upon the surface of calm water; in the other he fixed the body firm in a stream of water. Comparison of results showed a slight difference between the mutual reactions consequent upon equal relative velocities. From this he drew a paradoxical consequence, contradictory to the laws of relative motion: "In the condition of rest water offers more facility of division, and therefore less resistance, than when it is in motion."

The phenomenon as stated by Dubuat is actual, but the conclusion is false. The reason of this singular phenomenon is now known. In running water the liquid filaments have unequal velocities; while, if a body is moved in still water, the relative velocity of the water is the same for all the filaments. The relative situations are not the same, aud the difference of resistances observed does not contradict the laws of mechanics.

HYDRAULIC BUCKETTING ENGINE.

By PERCY WESTMACOTT.

From "Engineering."



During the construction of the Herculaneum Graving Docks, Liverpool, in the year 1863, Mr. George Fosbery Lyster, the dock engineer, communicated with the writer respecting the mechanical appliances for emptying these docks. The application of hydraulic power to the gates and capstans, etc,, having already been decided upon, it was considered expedient to contrive the emptying of the Graving Docks in conjunction with this same system, and thus save the erection of another steam-engine and plant for this special service, and at the same time secure a ready means of applying power especially at all times to serve leaks. Some arrangement, too, was required that would overcome or, at any rate, diminish the difficulties and inconveniencies experienced in dealing with water charged with rubbish from Graving Docks. The result was the construction of a machine upon a principle of bucketting large quantities of water at a time, devoid of clack valves, gratings, or other parts liable to choking or injury by floating matter, and that could be lifted clean out of the water to give free access to all parts when required. By this principle the same weight of water is discharged at each stroke, and thus no undue loss arises from the application of a constant hydraulic pressure, nor does the strain upon the parts or the conditions in working vary with the fall of water in the dock.

A scoop-shaped bucket attached to a piston rod is plunged at an angle of slight resistance into the water, and by a self-acting arrangement is turned round at the proper level, fitted, raised, and then discharged over an apron. The bucket of this engine, repre-

sented upon the accompanying outline plan, holds 14½ tons of water, and is constructed of wrought iron. It is poised upon a shaft attached to a sliding frame working in guides, suspended in the centre by the piston rod of the vertical cylinder which is planted above the well. The bucket when dropping is about equally poised on its axis, but when full and lifting, the back part is slightly in excess in weight. It is held firmly in position in plunging and lifting by means of catches which fall into a two-notched catch plate fixed on either side of the sliding frame. In plunging, these catches are, at the right moment, thrown out of gear by a float attached to the bucket, and in discharging they are disengaged by tappets fixed to the sides of the well. The weight of the float when out of the water forces the catches into the notches. Under the nose of the bucket another small float is fixed for the purpose of swinging the bucket quickly round to fill so soon as the catches are thrown out of gear by their float, and to bring this motion of the bucket up gradually, wooden floats are attached at the back which also serve to steady the bucket as the catches fall into gear. Check chains fitted with springs are applied to either end of the bucket. To insure the catches falling into place for the plunge, a cam on the bucket is made to strike a tappet fixed at the back of the well, should the bucket in swinging round not angle sufficiently in itself for the catches to fall into gear. The bucket with its attachments is counterbalanced by weights rocking in the guides of the well. In discharging, the catches are thrown out of gear by tappets, and 2 rollers in front of the bucket are pressed against inclined rubbers, and thus cant the bucket over upon the flap of the apron. Two discharging levels are provided, and the tappets, rubbers, cams, aprons, and flaps are arranged accordingly. The valves which regulate the motion of the piston are not shown in the diagram. They are planted upon the ground level, and motion is transmitted to them by that of the bucket through the agency of levers and cranks, and a stiff grooved rod passing down from the top to the bottom of the well. The lifting and lowering valves are mitred and balanced, and are reversed by a small hydraulic cylinder, the valve of which is acted upon by tappets. In order to bring up the speed of the bucket more gradually at the extremes of the stroke, throttle valves are introduced, which are also acted upon by a lever attached to the vertical grooved rod. A valve for governing the extreme speed is placed in the pressure pipe leading to the machine. The engine is started, stopped, and regulated by an ordinary stop valve, and a small pipe and cock is attached to the cylinder whereby the attendant can work the bucket up and down when required, independently of the working valves. It will be seen that when the bucket is up all essential working parts are out of the water, and therefore quite free of access.

The minimum lift at the high level discharge is 7 ft. and the maximum 23 ft., and about 5 ft. more stroke is required for tipping up the bucket. The usual average speed of the bucket in plunging or lifting is about 3 ft. per sec. The filling is effected in 5 secs., but the emptying occupies from about 12 to 15 secs. owing to a contraction that had to be made in the front end of the bucket to suit the existing masonry in the well. This latter operation with a free mouth to the bucket should not take more, if so much time as the filling.

The coefficient of effect obtained by this engine is as follows: At 7 ft. (minimum) lift .4; at 23 ft. (minimum) lift .6; average .54; which will be found to compare not unfavorably with other appliances under the same conditions of working, but the loss occasioned by the choking of passages and gagging of valves or paddles is altogether avoided by this system, which, for this reason, is peculiarly well adapted for sewerage purposes.

Mr. R. B. Grantham was of opinion that this system would work admirably for sewerage purposes. The existing bucket or plunger pumps were liable to be choked by the hair and other impediments common to sewage, and injured by gravel and sand.

Mr. Bramwell was doubtful whether this was the best implement for lifting sewage. For short lifts he thought it would not be economical, and for very high lifts it was manifestly inapplicable. But where there was a lift of about 20 ft., and the sewage had to be delivered on the spot, then he thought the plan would be

useful. He wished to know whether the tipping arrangement was automatic, so as not to be interfered with by changes of level. Also why it was preferred to tip rather than to take in the water by a bottom valve.

Mr. Westmacott said that the arrangement was automatic. The valve was not used, simply because it was not thought desirable to employ anything that might be liable to obstruction. The bucket always caused a scour, and so kept the well clear. He thought there would be no difficulty in making a 40 ft. lift. Beyond that height there might be two or more buckets, each above the other.

HENDERSON'S PATENT PROCESS FOR REFINING CAST IRON.

In the November number of this MAGAZINE is an article on Mr. James Henderson's new process for the production of wrought iron and steel. It was then stated that interesting experiments had been made with fluorspar and hematites, for refining cast-iron, which we have now the pleasure of giving to our readers. The new patent process supplies a more effective and economical process than the English finery, or the German reverberatory furnace processes for refining cast-iron. It is very simple, and does not require any fuel, labor, or expensive apparatus; and there is no loss of weight of iron, as the impurities go off in vapor. The cost of refining is less than one-twentieth of that of the English and German processes; and its effect is more thorough than is possible by those systems.

The agents used are fluorine and oxygen combined. The fluorine is derived from any fluoride, and the oxygen from any substance containing or capable of evolving oxygen, which is adapted to use in the manufacture of wrought iron and steel. Fluorspar and pure rich iron ores are the most available and the most economical substances of producing these agents, and are applied finely powdered, and mixed, and placed in receptacles preferably, so as to act from the under side upwards upon cast-iron in its molten state.

The most economical mode of application of this process is to treat the cast-iron in the condition in which it flows from the blast furnace, with fluorspar and iron ore, applied in the "chills" or pig moulds, used at blast furnaces, by being spread over the bottom of the moulds. The iron when tapped from the blast furnace flows into the moulds thus prepared; he heat of the iron melts the fluorspar, and by reason of the affinities of these substances for silicon and phosphorus, these impurities are removed, in the form of *vapor*. The reactions in the "chills" are similar to those of the boiling puddling process, and last about five minutes. The metal during this period is covered with jets of flame and smoke. The resulting metal with respect to silicon and phosphorus, is as pure as wrought iron.

It is preferable to use iron ores containing the largest amount of oxygen and the least silica and phosphorus; these conditions exist in the "washed" iron sands of Canada and Long Island, and the specular and hematite ores of Lake Superior. When using the ores of Lake Superior, varieties that are the easiest to reduce to powder are preferred; and the ordinary edge running apparatus, with cast iron rollers, revolving in a pan, is an excellent one for the purpose. The fluorspar and fine ore are passed through a sieve of not less than 400 meshes to the sq. in., and afterwards mixed so thoroughly as to appear to be one substance, in the proportion of 1 part of fluorspar to 2 parts by weight of iron ore, and spread $\frac{1}{4}$ to $\frac{3}{8}$ of an inch deep over the "chills;" then the iron is run upon them so as to form slabs 1 in. thick.

The article in our November number described refined cast iron produced in the reverberatory furnace. It will be seen by comparing the analysis of the refined metal of this process with the analysis of that of the reverberatory furnace process, that they are analogous, except that the latter contains no silicates nor graphite. The refined metal of the pig mould process saves the fuel and time taken for refining by the reverberatory furnace process and shortens the time of producing steel or wrought iron by that process fully 40 minutes. When using the refined metal

of this process two workmen can take charge of 5 ordinary boiling puddling furnaces making steel, and 6 furnaces making wrought iron; as the only labor necessary is "balling" the metal and removing it from the furnace. When highly carbonized steel is made, "balling" is not required, as the metal will be fluid enough to run from the furnace into ingot moulds. The economy of the process consists in the saving of the labor of 8 workmen making steel, and 10 workmen making wrought iron; and in the superior quality of the result, as compared with puddling the refined metal. The time occupied by the conversion of the refined metal into steel and wrought iron by the process without puddling is about the same as that usually taken in puddling pig iron.

Ordinary coke pig iron, smelted near Pittsburg, from a mixture of hematite ore and mill cinder, has been treated by this process. The refined iron was afterwards puddled, and once heated and rolled into merchant bar iron. The pig, refined cast, and wrought iron have been analyzed by Mr. W. M. Habirshaw, analytical chemist, of this city. These analyses are annexed, also analyses of refined cast-iron, by the English finery and German reverberatory furnace processes, and of the highest standard qualities of English, French, Swedish, and Russian wrought iron, taken fron "Percy's Metallurgy" and "Ure's Dictionary," are given for comparison.

	Coke Pig Iron.	Patent refined Cast Iron.	Bar Iron.
Carbon (combined.)	0.2040	0.3613	.....
Carbon (graphite)	2.7685	2.5066	.....
Silicon	2.3096	None.	None.
Slags (Silicates)	0.3623	0.2983	.....
Phosphorus	0.4196	0.1029	0.0087
Sulphur	0.1298	0.1269	0.0438

	English Finery Process.	German Reverberatory Furnace Process.	
	Refined Cast Iron.	Pig Iron.	Refined Cast Iron.
Carbon	3.07	.....	.....
Silicon	0.63	4.66	0.62
Phosphorus	0.73	0.56	0.50
Sulphur	0.16	0.04	0.03
Silica, Alumina } Slags	0.44		

Analyses of Wrought Iron.

	English.	French.	Swedish.	Russian.
	Low Moor.	Petin, Gaudet & Co.	Hoop L.	C C N D.
Carbon	0.016	0.143	0.087	0.272
Silicon	0.122	.....	0.115	0.062
Sulphur	0.104	0.058	0.220	0.234
Phosphorus	0.106	0.030	0.034	.....

On comparing the analysis of the refined cast-iron of the patent process with those of the English and German processes, it will be seen that while the refined iron of the new process contains *no silicon*, that of the English and German processes contains 0.63 and 0.62 per cent. respectively; and, compared as regards phosphorus, the German process reduces it from 0.56 to 0.50 per cent., or about 0.06 per cent., and the new process reduces it 0.32 per cent., or over 5 times as much

phosphorus is removed by the new process as by the other processes. The slags or silicates are 0.15 per cent. less than in the refined iron of the English finery process.

The analyses of the patent refined cast-iron, compared with that of the English wrought-iron, show that whilst the wrought-iron contains 0.122 per cent. of silicon, the refined metal contains none; and compared as regards phosphorus, they are about the same.

The analyses of the puddled wrought-iron made from the refined cast-iron by once heating and rolling the "muck" bar, shows a purer quality of iron than the most celebrated brands of Europe, produced from the purest ores, with charcoal. The economy of the refined metal in saving cost of labor, fuel, etc., for the puddling process, has been fully demonstrated by numerous trials. When all of the advantages of the process are realized, about one-half of the cost of converting cast-iron into wrought-iron can be saved; and there is an improvement in the quality equal to the difference between ordinary forge pig-iron and charcoal iron.

These advantages are:

First.—Better quality, which is due to the purity of the refined metal; as good qualities are produced from it as from pig-iron made from the best ores smelted with charcoal.

Second.—The refined metal, being as pure as wrought-iron, with respect to silicon and phosphorus, requires merely decarbonizing, with less skill to work it, and greater certainty of the quality of the product.

Third.—Large saving in the cost of production, owing to the shortening of the time of puddling, which is caused by the removal of a large part of the impurities by the refining process. White refined iron is decarbonized in 12 to 15 min., and a "heat" or charge of 500 lbs. is puddled in 55 min., including time of charging, melting the iron, and stirring or puddling and "balling" and removing it from the furnace; gray forge iron requires 65 min., and foundry iron about 70 min. Seven "heats" or charges to a "turn," or a day's labor, are of easier accomplishment than five charges are from the pig-iron from which it was produced; the five charges now require about 10 hours to convert pig-iron into wrought-iron. It is possible to obtain with the patent refined metal, by employing three sets of workmen for the 24 hours instead of two sets as is now customary, twenty-one charges in 24 hours instead of ten charges; and allowing sufficient time for repairs, the production of any iron works may be doubled, without additional investment of capital and without additional cost of repairs.

Fourth.—Saving of fuel per ton of iron produced, amounting to one-half, caused by increased production.

Fifth.—Reduction of general business expenses per ton of iron, amounting to one-half, caused by increased production.

Sixth.—Reduction of wages by reason of the diminished labor (of about 40 per cent.) per ton of iron.

Seventh.—The puddling furnace cinders of the refined metal contain but about one-fourth of the phosphorus, as compared with the cinders resulting from the use of pig-iron; and, when smelted, produce better qualities of pig-iron.

The cost of refining in the pig moulds is very little. Fluorspar is a cheap material, and but about 70 lbs. are required to refine a ton of iron. In some localities the cost will be compensated by the saving of the fuel and lime which would be required to reduce the puddle cinders of the refined cast-iron to pig-iron, as they contain no silica, and will require less fuel and limestone. The residue of the fluorspar and oxide (when iron ore is used), after being used in the process, is agglutinated and remains in the pig moulds, and is pure lime and deoxidized iron ore, and is available as so much ore and lime in the blast furnace.

The following is a simple method for detecting the presence of wood fibres in paper or fabrics. The reagent employed is a weak aqueous solution of sulphate of aniline. If a drop of this liquid, on a pointed glass rod, be applied to paper, if wood be present, even in minute quantity, an intense yellow color will be immediately visible; but the test is only applicable when the wood pulp has been prepared in a mechanical way. Chemically prepared wood does not yield the same reaction.

Beton Coignet is being extensively manufactured in Brooklyn, N. Y.

THE BUBBLING AND SCINTILLATION OF IRON.

Translated Abstract from "Comptes Rendues."

The writer has shown, in a previous article, that steel and cast-iron do not boil or scintillate, if they are melted in an atmosphere of hydrogen or carbonic acid, so that the phenomena of the metal when melted and poured cannot be attributed to the escape of a reducing gas taken up during the melting. It is his opinion that the bubbling and crackling is caused by a reaction of oxide of iron upon the carbonic compounds. In support of this view the following is offered:

Iron or steel, in the crucible, is heated for a long time before melting; it is covered with an oxidized layer, and within this there is a thin layer of carbonized steel; the interior remains unchanged. When the inner portion is melted it breaks through the resisting envelope; the crucible is filled with melted steel containing the external envelopes. These react upon the carbon of the iron or steel, and cause the generation of carbonic acid gas.

Another cause of the formation of this gas must not be left out of sight. If the metal is thoroughly melted, when the crucible is opened air enters; the stream flowing into the mould is oxidized at the expense of the air, and a mixture of oxide and iron, containing carbonic acid, with air, is introduced into the mass; these continue in a condition of mutual reaction until solidification, and possibly longer.

The scintillation of iron, when heated in oxygen, has been attributed by the writer to escape of a gas previously absorbed. Experiments have confirmed this theory, but at the same time have suggested an additional cause.

Pure iron and common forge-iron do not crackle, if melted in a well-closed earthen crucible, or in a porcelain tube, in an atmosphere of hydrogen or carbonic acid gas. The phenomena seem to be different, if the same iron is placed in a shallow vessel of lime, and submitted to the direct flame. If care is taken to furnish the flame with an excess of hydrogen, the iron is, for the most part, oxidized in mass, while it is melting; and if, after thorough melting, the flame is removed, a lively scintillation and bubbling is often the consequence.

The following experiment was made: A shell of lime was filled with pure oxide of iron, pressed into small cylinders; a cover was put over these, and they were melted by the blowpipe, so as to assure a maximum excess of hydrogen in the flame. As soon as the mass was melted the flame was removed, but the cover was not removed. The mass stiffened on the surface; this rose, and finally, after cooling, crackled, without emitting sparks. If the mass was kept too long in a melted condition, the crackling did not occur; probably because the oxide and the lime had combined. A little silicious acid also prevented this phenomenon.

The same effects occurred when the melting vessel was made of magnesia or of pure protoxide of iron compressed.

Notwithstanding the excess of hydrogen in the flame, reduction of the oxide to metallic iron never ensued. Indeed, since the experiments of Magnus it has been settled that hydrogen in the presence of steam never reduces the oxide of iron at any temperature. It follows that bubbling and crackling of iron melted in a lime vessel is caused by a gas which is absorbed by the oxide contained in the flux.

The melting of pure iron in a current of hydrogen is difficult, as the porcelain tubes generally soften before the metal is melted; but the Schlösing blow-pipe may be used. Experiments were made with quantities.

If the iron was entirely melted it remained free from bubbles, showing that the hydrogen was not absorbed by the melted metal. Besides, the specific gravity of bars not hammered was increased, showing that the density of iron melted in a current of hydrogen is greater than when it is melted in an atmosphere not reducing. Iron melted in a hydrogen current, containing no trace of carbon was found to be easily wrought when in a red-hot condition without the usual precautions. It approaches copper in softness and ductility, and is ductile when cold. Forge iron melted in the crucible is, on the contrary, considerably harder. The large and shining facettes on its surface of fracture are like those of iron

subjected to continuous vibrations. At red heat it is with difficulty drawn into wire, and to forge it easily it must be subjected to long welding heat; but it never hammers as well as the iron prepared as above. While hardening in the crucible it experiences an obvious contraction, so that a cavity is often formed within; a circumstance likely to lead to incorrect calculations of specific gravity. A bar of the latter iron cut into thin laminæ yields, under continued heat in hydrogen, a considerable quantity of water, and after cooling there is a decrease in weight, mostly due to the removal of oxygen originally contained in the metal. In some cases the diminution was 0.5 per cent.

ON THE CONSTRUCTION OF SEWERS IN RUNNING SAND.*

By T. MELLARD READE, C. E.

From "The Building News."

All who have had experience in engineering are aware that the most valuable knowledge is often that acquired while contending with unforeseen difficulties. The introduction of the present subject to the notice of the British Association will, therefore, we hope, require no apology beyond the simple statement that some of the sewerage works intrusted to us having been executed in difficult sandy ground, we are desirous of recording, for the use of others, some of the experience necessarily obtained.

Probably no one who has not watched the process of laying sewers in ground similar to that which distinguishes the land on the Liverpool, Crosby, and Southport Railway, the whole distance from Waterloo to Southport, can form any idea of the difficulties that have to be encountered. The whole of that district is one mass of sand resting on a bed of moss and marl, varying from 10 ft. to 20 ft. deep below the surface, and, having no natural drainage (in consequence of the elevation of the shore line of sand hills) in wet seasons in the lower portions or slacks, flashes of water form.

The permanent water level in the driest seasons in these places is only a few feet below the surface, while, sink where you will, before you get to the depth necessary for a sewer you are sure to come to water. Now, water in gravel or rock is not difficult to contend against, but in fine-blown sand it forms a subsoil of running sand or quicksand of the most lively and insinuating description.

Sheet pile or trench as you may, it reams in between the sheeting in streams of sand, and also forces itself bodily upwards in the bottom of the trench by a species of disguised hydrostatic pressure. To keep open more than a short length of trench the full depth during the laying of the pipes is impossible, and consequently the difficulty of laying the invert of the sewer to a true gradient is immensely increased, while the low gradients demanded by the general flatness of the country require for the efficiency of the sewer extreme accuracy.

When practical, in order to relieve the ground of water, it is advisable, we find, when it can be done without timbering, to open out a long length of cutting about 5 ft. or 6 ft. deep beyond where the pipes are actually being laid. In our works, from motives of economy and other reasons, we have mostly used pipe sewers socketed, glazed, and jointed in fine cement. Theoretically, such pipes with cement joints should form impervious sewers, but they do not; with the ordinary system of laying, we know this to be impossible. The consequence is, that where you have several miles of pipes, the subsoil water that enters the sewers is enormous. Summer or winter the flow is unceasing, nor is this in itself a disadvantage, but rather the contrary, for the tendency of the flow is to keep the sewer sweet and clean. The Blundellsands main, which, with subsidiary drains, is about $2\frac{1}{2}$ miles long, in dry frosty weather last winter when gauged showed a discharge of 180 gallons per minute, $\frac{3}{4}$ of which at least would be subsoil water; and, apparently, except during rain, the flow does not materially differ at various seasons. This, then, as far as the water is con-

*Paper read before the Mechanical Section of the British Association, at Liverpool.

cerned, is a distinct advantage, but along with the water sand reams in and forms a deposit along the whole length of the sewer, which is only removed by frequent flushing. In every case where pipes are laid in running sand, however well and carefully the joints are made, we find this to occur. To get the cement to set before being washed into the sewer is no easy matter. In laying the pipes about 20 yards of timbered trench is opened at one time. A dam of sods, etc., is then formed across it in front of the pipes, and the sand between it and the pipes is dug out until a hole is formed, from which the water can be baled out into the trench above, from which it is pumped to the surface. When all is prepared, the pipes are lowered down into the trench one by one, the joints being laid on a bed of clay puddle 6 in. thick ; the joints are then made good with quick-setting cement, and the cement is covered all round with a good collar of clay puddle to prevent it being washed into the sewer. With very great care and judgment a good sewer may thus be formed, but not a water-tight one, and we always find that the subsoil is drained nearly to the invert in the very best and most carefully constructed sewer we have yet seen. This is a positive advantage, but the consequent admission of running sand—and it is astonishing how fine an opening it will ream through—is an evil which it would be well, if possible, to guard against. In addition to this, the sinking of the baling-out hole while laying the pipes has a tendency to draw the end pipes downwards, and thus interfere with the true gradient of the sewers. In all sewers in ground of this nature, we have also to form what is called a sumphole at the bottom of each manhole, or they would speedily get choked. By the aid of the flushing apparatus, which we shall presently describe, the deposit in the sewers is flushed into these sumpholes and then cleaned out at intervals. It is difficult to convey to any one who has not seen it the insinuating nature of this sand, but by attention and frequent flushing we find that well-laid pipe sewers in such ground can be kept clean and sweet.

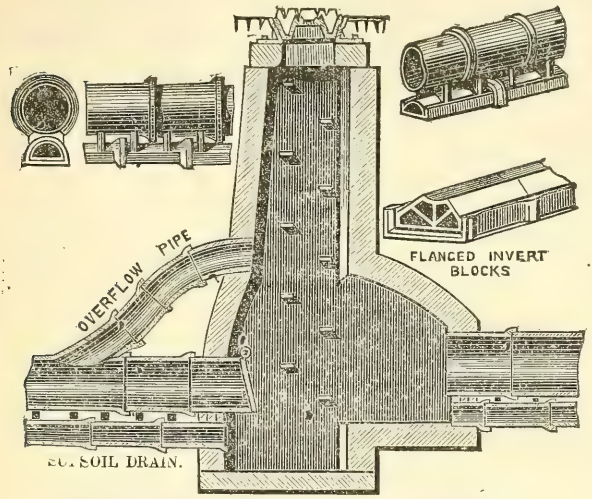
Though sewers are possible and effective laid in the manner just described, it is a matter of much care and attention to get them laid properly, and it is really essential that a clerk of the works should himself see every individual pipe laid. With all this, still imperfect joints occur, for as soon as the baling out ceases as the pipes are practically plugged up with a straw plug which is drawn through the sewer to keep it clean, the level of the water rises sometimes even above the top of the pipes, and the hydraulic pressure thus created will find out all imperfections and sometimes prevent the cement setting properly. Again in putting in the sumpholes the tendency is to draw the nearest pipes out of the level, and indeed the most satisfactory way of getting them in is to sheet pile them all round. Having had all these manifold difficulties to encounter, we set ourselves to try and devise some method by which greater care in and perfection of laying could be obtained.

The model of the subsoil drain and pipe-rest we now have the honor of showing you is partially the result of our experience in laying sewers in sand. At our suggestion Messrs. Brooke & Son, of Huddersfield, the fire-clay pipe manufacturers, have worked out the invention in a practical form, and we are now commencing to use it in the sewerage works at Birkdale. The primary object of attainment in this is to get a dry subsoil wherein to lay the pipes that the cement joints may have time to set and become water-tight, and by securing more time for the laying of the pipes, laying a greater length at a time, and the prevention of disturbance or drawing of the pipes while preparing the next excavations, to insure greater certainty and perfection in the gradients and junctions, and consequently the general system of pipe sewerage. That this is of the utmost importance none who practically understand the subject can doubt, for the difference between brick sewers and pipes often means whether sanitary work shall go on or be stopped.

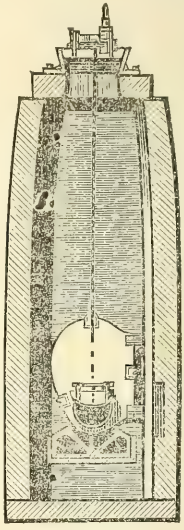
The subsoil drain, it will be seen by an inspection of the model, is an internal section, a semicircle, and varies in diameter according to the diameter of the superimposed sewers. For 2 ft. pipes we purpose using drains 1 ft. diameter ; for 1 ft. 6 in., 9 in. diameter ; and for 1 ft., 6 in. diameter. The length is the same as the pipes in the sewer, *i. e.*, either 2 or 3 ft., as the case may be. The larger pipes we use in 3 ft. lengths. Each pipe is socketed, and the sides being brought up

square, a shoulder is formed on which the movable bricks forming the rests (which also fit the top of the drains and the curvature of the pipes) are laid. The pipes in the sewer above are arranged so that they break joint with the subsoil drains, and the ends of each sewer pipe rest on the adjoining subsoil pipes. It will be seen that this arrangement secures ample space under the sewer for making the cement joints good.

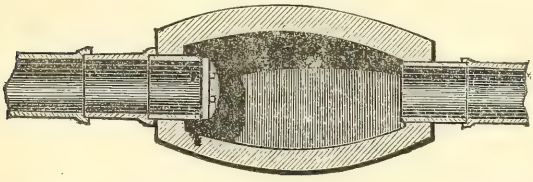
The operation of laying the subsoil drains is somewhat similar to that previously described as the mode we adopted for laying pipe sewers before employing this invention, the only difference being that the joints are made in clay alone, and from the small size of the pipes they can be handled and laid much more readily; slight imperfections in the gradients also will not be of the same consequence as in the sewers. When a sufficient length is

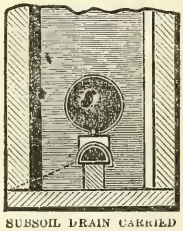


MANHOLE WITH FLUSHING VALVE AND SUBSOIL DRAIN.



STONE BOTTOM.

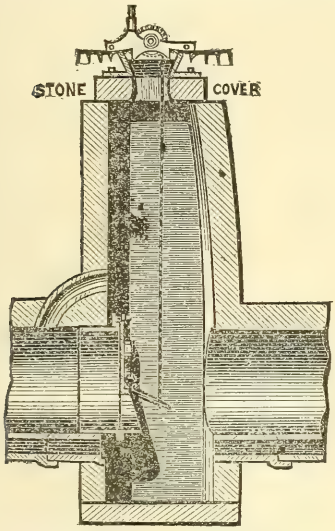




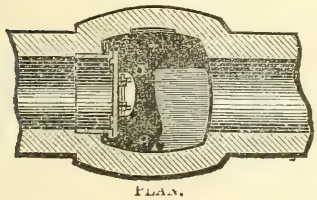
SUBSOIL DRAIN CARRIED THROUGH MANHOLE.

opened out, we commence laying the sewer pipes upon the brick saddles or rests, which have previously been accurately laid to the proper levels from sight rails in the usual manner. As this can be done without hurry or confusion, a more perfect sewer is the result. The subsoil drains are continued through some of the manholes, as shown in the engraving, and are united to the main sewer at intervals, discharging their contents into sump-holes which retain the sand that may be brought down by the water and which then can be readily cleaned out when necessary. In each of the intermediate manholes, where the subsoil drains are carried through, they will be fitted with a disc plug on the top for the purpose of flushing. When the flushing valves (to be hereafter described) are down, the removal of any of these disc-plugs will allow of any portion of the drain being flushed with a good head of water. It will thus be seen that while we retain all the advantage of subsoil water, we avoid the evils of running sand, which, if not attended to, accumulates in the bottom of a sewer, cakes with the sewage matter, and

obstructs the flow. Perhaps some may think that it would be better to keep the flow of subsoil water entirely separate from the sewage by continuing the drains through or round all the manholes, with provision for admitting the subsoil water into the sewers whenever required for flushing. Special cases undoubtedly require special treatment, and in the case of wet gravelly ground it may sometimes be an advantage when using the subsoil



SLUICE GATE TO BRICK SEWER.



PLAN.

drains, to carry out a separate system; but in running sand the case is different; for without a certain number of sump-holes the drains would infallibly get choked, and to fit the subsoil drains with separate manholes and sump holes would unnecessarily complicate the sewerage works, besides introducing other evils. As a rule, we are in favor of introducing subsoil water into sewers, as a constant flow tends to sanitary efficiency; but where the sewage is to be used for irrigation it may in some cases render it difficult to dispose of the whole of the sewage, especially where pumping has to be resorted to. There are, however, to our minds so many objections to a separate system that we should not adopt one except for very special reasons. None can lay down rules and formulæ for inflexible guidings in engineering matters; all that can be done is to state principles, and the intelligence of the engineer must be his guide in their application. Though primarily the object sought in the invention of the subsoil drain and pipe rest was the more perfect construction of the sewer proper, it possesses the additional merit of reducing the permanent level of the subsoil water to a lower level than does the ordinary sewer, and is a distinct provision for that object, instead of an accidental accompaniment of sewerage works.

Brick sewers it is common to construct with invert blocks when the subsoil is wet, and they make a very true foundation to build the sewer upon. In running sand we find it very much better to construct the inverts with flanges as shown, and to bed them in clay as a precautionary measure for keeping the sand out of the sewer. After the sewer is completed it is unnecessary to keep the invert drain open, as the brick sewer being porous admits the subsoil water and effectually drains the ground. During the construction of the sewer the invert blocks act as subsoil drains, and very much facilitate the work. The experiments we have already made with the subsoil drains have thoroughly satisfied us as to their efficiency. We find that when they are laid the sewer can be constructed with extreme facility with perfect joints, and that the effect of the sewer-pipes breaking joint with the sub-drains is not only to strengthen the sewer at the joints and prevent drawing, but to insure perfection in the gradients. The subsoil drains are, in fact, a foundation for the pipes of the sewer, and the sewer itself can be as readily constructed upon them as if the ground were perfectly dry. Those who have had experience in running sand will see that this is no small advantage, independently of the draining of the subsoil which will necessarily occur. We have begun to use the subsoil drains or "blocks," as the workmen call them, in the sewerage works we are carrying out at Birkdale, and when by their aid we get the 10,000 yards of intended pipe sewers completed, we shall

be in a position to state the results, and to give further information to any engineers who may ask for it.

For all sewers, flushing is of the utmost importance ; yet how seldom is any provision made for it except by the introduction of a water company's hose, which combines the minimum of effect with the maximum expenditure of water ? In all our works we introduce flushing valves of the forms shown in the engraving, but for sewers in sandy districts they should be used at more frequent intervals, for unless we have an abundance of scouring force we are never safe as to the permanence of the sewer. Frequent flushing is of the utmost importance ; it is of no use making elaborate provisions that cannot be used when most wanted, or letting apparatus rust for want of efficiency in the executive. Local boards too often think they have done everything when a sewerage system has been carried out ; that it should be constantly attended to is of almost equal importance. No apparatus can dispense with intelligent supervision, but we cannot speak too strongly on this point, for, although it is a truism, local authorities act as if everything were self-acting, and only examine a sewer when it is time to pull it up. Unfortunately, engineers are partly responsible for this state of things, for their works formerly were, from the absence of provision for flushing, apparently constructed on the same supposition. Flushing gates for large sewers are frequently used, but we are not aware of valves being used by others than ourselves for flushing pipes with their own waters. That all sewers should be flushed with their own waters should be an axiom of engineering, for otherwise in drought, when water is scarce, and the deleterious decomposing matters which invariably accumulate in the best constructed tributary sewers most require removing, they stand a good chance of being left to breed fevers and other diseases. By having the valve, consisting of a cylindrical barrel, of the diameter of the pipe it is connected with, built into the manhole, and fitted with a flap valve hung to a diagonal face with a brass pin in the hinge, the water accumulates up the sewer until it rises to the safety overflow, which should be below the level of any adjoining cellars. When this occurs, sufficient hydraulic power is accumulated to sweep all deposits out of the sewer below to the next valve. It must be understood that the sewer above the valve for a certain distance also shares in the cleansing operation ; but the force is greatest near the valve, and it decreases until it reaches a distance sufficient for the whole of the water to get into "tram," when the scouring force is equalized, though much diminished. We have used these valves in all our works for the last five years, and find them invaluable. They, in fact, render that possible which would otherwise be impossible. We use them up to 2 ft. diameter, but for the larger sizes a small portable crab winch, shown also in the engraving, capable of lifting one ton, and which fits on the manhole cover, and to the barrel of which the chain of the valve is temporarily attached, is employed to lift them. For brick sewers and sewers of a larger diameter, the flushing-gate manufactured by Mr. Samuel Harrison, of Soho Foundry, Liverpool, is used. When not in use it lies back against the side of the manhole, and is held in its place by a catch. When closed and screwed up by the handscrews, the water accumulates behind and keeps it tight against its face until reaching the overflow. On to this gate is fixed a circular valve near the invert of the sewer, precisely similar to that described for the pipes, and when it is required to flush the sewer it is suddenly lifted, a rush of water takes place along the invert and sweeps all before it. When all has escaped, the gate can be thrown back readily, as it is relieved from all pressure. The flow of water being directed to the invert is more effectual than it would be were the gate itself opened, and the flushing force being applied through a smaller orifice lasts longer and is more sustained. The great advantage, however, is that a very large sewer can thus be flushed without any of the mechanical aids necessary for opening a large flushing gate against pressure, and consequently the cost of the gate is not half that of the ordinary sluice. At the termination of all the sewers we provide a flushing-box and pipe for filling the upper part of the sewer above the first valve, as the natural flow is there, of course, only small. The gullies we use are easily cleaned of sand, and have the advantage of remaing trapped during great drought, as 5 in. of water must evaporate before the untrapping takes place.

The form of ventilator also manufactured by Mr. Harrison, of Liverpool, though applicable to all situations, is especially so for districts where either much loose sand is blown about, or where there is a heavy traffic and consequently muddy roads. The ordinary form, consisting of a brick chamber and separate ventilating grid, under such circumstances soon gets choked with mud or sand, and the consequent damp also destroys the efficiency of the charcoal. In all sanitary works, as we before said, we must have efficient superintendence, and the best method of making that superintendence efficient is to make the work easy and light. It will be seen that the ventilator consists of a combined manhole and ventilating cover. The air grid is in the manhole cover itself, the frame which it fits into being lengthened into an air shaft which is perforated at the side, and the bottom is sealed with the movable mud basket, to prevent any passage of air from inside to outside except through the deodorizing charcoal basket. It will be seen that during a heavy fall of rain, or should the cover accidentally be fixed lower than the road and surface water enter, the water may overflow the mud basket. To avoid damping the charcoal, this is provided for by the overflow pipe, which is carried down into the water of the sump-hole, which traps it and prevents it becoming a channel of communication between the internal gases and the external air. A small brick chamber or flue is built at the side, covered with a cast-iron plate to receive the paving. The mouth of this in the manhole is fitted with an iron frame to receive the charcoal basket, and the upper part communicating with the perforations in the side of the shaft of manhole cover, and thence with the external air. It is evident from this arrangement that the mud basket can be readily lifted out by its handles and emptied of its contents, and also that no inspection of the sewer can take place without this preliminary operation being guaranteed. We have now described pretty fully our arrangements for sewering wet sandy ground. Many of these inventions we use also in other places, but the original suggestions for them have arisen from our contentions with sand. In other subsoils, with quick gradients, we only use sump-holes in those manholes where the valves are fixed, carrying the sewer through the intermediate manholes by open culverts, constructed in brick, of the form of the sewer, and in fact forming the bottom of the manhole, with a shoulder on each side. Undoubtedly the most efficient system of sewerage is that which sweeps all matter away at once to the outlet, and sump-holes should only be used to prevent the possible choking of the sewers. The conditions of perfect sewerage may be summed up thus: True gradients, as quick as can be obtained, but increasing gradually from the outlet to the branch sewers; perfect construction; requisite depth below the surface; provision for draining the subsoil water to the level of the sewers; adequate flow of water in the sewers; abundance of flushing power; constant flushing and sufficient ventilation; and real active supervision in the executive. But above and beyond that, the abolition of cesspools, middens and stagnant pools, together with a perfect house drainage, are essential. Often when sewerage works are completed the whole of their utility in a sanitary point of view is vitiated by criminal neglect of the house drainage. It is not merely sufficient to connect existing drains or the overflows of cesspools with the sewers; they should be thoroughly examined, abolished, and the drainage reconstructed where necessary. We have no doubt that defective house drainage is in most cases responsible for local outbreaks of fever and other diseases, rather than the main sewers. We have not treated of the ultimate disposal of sewage, as that is not within the scope of this paper, but may say that we firmly believe irrigation to be the only absolute remedy, and that in time works for effecting it will be considered an integral portion of any sewerage system. That time has not yet arrived, but we are rapidly approaching it, and we wish the movement "God-speed." To consider sewerage complete when the sewage is only turned into a river, or on to a shore, is a barbarity unworthy of the age, and it is the duty of Government, and also we hope its intention, to absolutely prohibit the fouling of the watercourses and shores, and so force the question on to its only logical conclusion.

During the siege of Strasbourg the cannon were heard at Baden, 15 miles distant.

BLASTING ON THE UNION PACIFIC RAILROAD.*

The cut was through dark blue limestone which had been partially taken out so that there was left in it a mass about 100 ft. long and 18 ft. deep, with the ends well squared up. The average width thrown out being 24½ ft., the total amount was 1, 633 cubic yards.

The original depth of the cut was 31 ft., of which 13 ft. had been removed.

The powder was put in 2 wells, 34 and 20 ft. respectively from the 2 faces, leaving about 46 ft. between the 2 blasts.

The first well was sunk vertically to grade (18 ft.), two chambers were then excavated along the axis of the cut each 6 ft. in length. The second well, also 18 ft. in depth, had a slant of about 10 deg. towards the first well, with a chamber in the same direction about 4 ft. long.

The wells, which were as small as it was possible for a man to work in, were blasted with nitroglycerine. The first with 2 chambers, required 9 eight hour shifts of 2 men each, and 15 lbs. of nitro-glycerine.

Cost of 1st well.

Labor 18 days at $3	$54 00
Nitro-glycerine, 15 lbs. at $2	30 00
	$84 00

The second well with 1 chamber required 6½ eight hour shifts of 2 men each, and 11 lbs. of nitro-glycerine.

Cost of 2nd well.

Labor 13 days at $3	$39 00
Nitro-glycerine, lbs. at $2	22 00
	$61 00

The first well was loaded with 78 and the second with 33 kegs of powder, 111 kegs in all, which at 25 lbs. per keg is 2, 775 lbs. or about $1\frac{7}{10}$ lbs. per cubic yard. This large amount of powder was used on account of the rock being at the bottom of the cut, and firmly bound by its sides. Also from the nearness of the track, which made it desirable to throw as much material out of the cut as possible, to save time.

The powder was first covered with logs firmly wedged into the wells, and then tamped with fragments of stone well rammed in layers. Three fuzes were used for each charge, cut carefully of the same length. The blasts were successful, exploding within a few seconds of each other. Only about 600 cubic yards of material were left in the cut, which were removed by 6 eight hour shifts of 18 men each.

Cost of blasting and removing 1,633 cubic yards of rock.

1st well	$84 00
2d "	61 00
111 kegs of powder at $10	1,110 00
120 ft. of fuze at 3 cents	3 60
Logs, loading, etc., about	25 00
Loading material left in cut into carts, 18 men 6 days at $3	324 00
	$1,607 60

Or less than $1 per cubic yard. To which is to be added for superintendence, carting, etc., about 10 per cent,, making a total of $1.10 per cubic yard.

*A paper read by E. P. North, Civil Engineer, before the Am. Society of Civil Engineers.

REPORT ON THE SUEZ CANAL.

By T. LOGAN, C. E., Executive Engineer.

From "The Artizan."

In continuation of my report on Irrigation in Egypt, now submitted, and in accordance with a letter dated November, 1869, from the Home Government, I have the honor to forward a report on my late inspection of the Suez Canal, which, through the kindness of the Canal authorities, I was enabled to do, in a satisfactory manner.

On my first visit to Egypt, in 1856, I could not help observing that, though the harbor of Alexandria is close to the most western mouth of the Nile, yet during these last 3,000 years or so, no perceptible change in the depth of the harbor has been observed, so far as I could learn; and on my return voyage, I made particular inquiries on the subject, which led me to the conclusion that the current which enters the Mediterranean at Gibraltar, passing along the north coast of Africa in an easterly direction, which ulti-

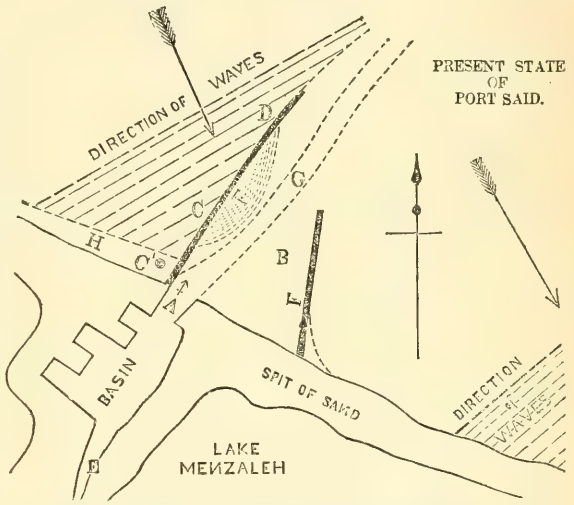
mately passes along the south coast of Europe, causing a considerable current through the straits of Messina, and ultimately returning to the Atlantic by an undercurrent through the straits of Gibraltar, must be one of the chief causes why there should be no deposit in the harbor of Alexandria, and that we should look for it along the coast east of the mouths of the Nile. So satisfied was I on this had to defer my visit till this present occasion on my return to India.

While in England, however, I had on two or three occasions read papers in connection with this question — the "abrading and transporting powers of water" — which, I believe, increases in some ratio as the velocity increases, and decreases as the depth increases; so I may now simply state that my late inspection confirms these views, and that I found that a considerable deposit has taken place, and is still going on.

I was informed by the engineer at Port Said, that it was during the fall of the year that deposits chiefly took place, that is, while the Nile is in flood, that the prevailing wind was northwesterly, but towards the afternoon it usually veered round to a northeasterly direction; but any one who has sailed in the Mediterranean knows that the winds are not constant like the "trade winds," or the monsoons, so, though the prevailing winds may be northwestern, it is by no means intended to affirm that there are never easterly gales along the coast. Now, if the wind is the sole cause of the transport of the Nile silt, it can only be by the waves breaking on the beach; and, if so, surely in these last 3,000 years some of this silt would find its way westward to Alexandria, and also the deposits at Port Said would vary more according to the winds rather than to the floods down the Nile; consequently, as these floods bring to the sea this earthy matter, and fresh water being lighter than that of the sea, the fresh water holding this in suspension floats on the salt water, and by this current in the Mediterranean is transported eastward, ultimately uniting with it, and depositing its load along the coast.

point that I made arrangements to remain in Egypt for a short time on my return home in 1867, so that I might visit Port Said, and see if there were not deposits taking place at that spot, for I considered the breakwater there must act in the same manner as spurs on our rivers in Upper India, and cause a deposit east and west of them. Sickness, however, prevented my being able to remain in Egypt, so I

FIG. 1.



C', Lighthouse; E, Canal; F, sand and mud deposit; G, deepwater channel; H, land reclaimed. The arrows point to prevailing winds.

By the accompanying sketch, Port Said, it will be observed, is on a narrow spit of sand which runs along the coast, commencing near the most eastern mouth of the Nile, and extending eastward for many miles further. Behind this spit there is the shallow lake Menzaleh, while on the northern face of it is the Mediterranean Sea.

The slope that the sea beach here takes is as near as possible 1 in 300;* the depths along the site of the present breakwater, previous to commencing work, varied from 1 to 6 miles.

The advance along the sea coast on the western side of the breakwater is considerable, as it extended along the beach

* The slope of a sea beach appears chiefly to depend on the nature of the materials it is composed of. Thus, at Madras, where the sand is very coarse, the slope seaward is comparatively steep, though exposed to a heavy surf; while at Weston-super-Mèr, on the Bristol Channel, where there is clay, the slope is barely 1 in 500, while where there is sand it is about 1 in 100. The Nile sand is not coarse, being much the same as the sand in Upper India. Where there are pebbles and boulders the slopes increase accordingly, varying according to the size and beat of the sea.

westward 549 metres in November, 1861, when it had only advanced 70 metres seaward.

The advance in—

June, 1864,	westward,	about	1,000	metres	and 140	seawards.
March, 1865,	"	"	1,500	"	160	"
Nov., 1866,	"	"	1,800	"	225	"
Jan., 1867,	"	"	2,000	"	265	"
June, 1868,	"	"	2,200	"	320	"

From this it appears that the land which may be reclaimed already covers an area of little short of 100 acres, and as it protrudes out into the sea, before long this reclaimed land will become the favorite site for private residences, owing to the sea breeze, and the value of this property will no doubt hereafter go a considerable way to repay for any future extension there may be necessary for the breakwater.

The present advance seems to be at the 10 metre or $5\frac{1}{2}$ fathoms depth—some 75 yards—yearly, while in the same period the sea has receded some 50 yards a year; but I do not anticipate that the advance will be so rapid in future years as it has been up to the present time; for, as the deposit extends seaward, so will it extend westward six or seven times as far: thus the area will increase over which there will be deposit in the same ratio as a triangle having its side in the proportion of one side perpendicular to six or seven horizontal.

On the west side of the breakwater, that is, the exposed side, I observed a very remarkable fact when examining the sections, namely, where the depth of the water exceeded three metres it was always deeper away from the breakwater than just at the side of it, but where the depth was less at the side than three metres it was shallower. There was a similar effect on the east or harbor side, and this probably arises from the beat of the sea on the breakwater agitating the water between the blocks and thereby preventing deposit in their vicinity.

Regarding the deposit on the east or harbor side, it is not such a serious matter as I feared, for so long as the silt only comes through between the blocks and not round the outer end of the breakwater, I do not anticipate much trouble, for in the former case the best plan is to leave it alone and keep the deep channel for ships well away from it.

At first this deep channel was 150 metres from the breakwater, but now it is 200 metres; I think it would be still better to have it removed 250 metres away from the breakwater up to the point where the sea reaches, but beyond this, and all the way inland, there can be no objection to dredging close up to the breakwater; for where the deposits on the west side of it are level with high water, it is evident there can no longer be a passage of silt through the breakwater; and as the blocks of Beton were in the first instance deposited in comparatively deep water there can be no danger of disturbing them; consequently a wharf along this portion could be constructed at little expense, for ships to lie alongside of it.

The deposit along the east side of the breakwater where it had silted up to high-water mark, appeared to be of much lighter consistency than on the other side; for while on the west or Nile side, the deposit was sand, on the east side there appeared to be a large admixture of mud, and the more inland the more did mud predominate.

The ship I passed through the Canal in was anchored about opposite the light-house at the point A in Fig. 1, and on heaving up the anchor, a quantity of Nile mud was attached to the chain. Now as this was in the line of the spit of sand before referred to, it appears that only fine mud is deposited at this spot, and as sand is the chief substance held in suspension by the waves beating on the shore, this I think convincingly proves that the water in the harbor opposite the Light-house cannot be much agitated. And as I could not observe any current in the canal, and the water was comparatively clear at the upper end of the Grand Basin, we may rest satisfied that there is no great danger of large deposits either in the canal itself or the basin, so what deposits take place will for the future be chiefly beyond the Light-house.

The important question now to consider is: Will this deposit be to such an extent as to endanger the navigation, and will the dredging here be so expensive as to make the canal an unprofitable undertaking in a financial point of view? To this would I beg to draw particular attention, for in my opinion the chief difficulty in working the canal and keeping an open channel lies between the Light-house and the open sea, all other difficulties from

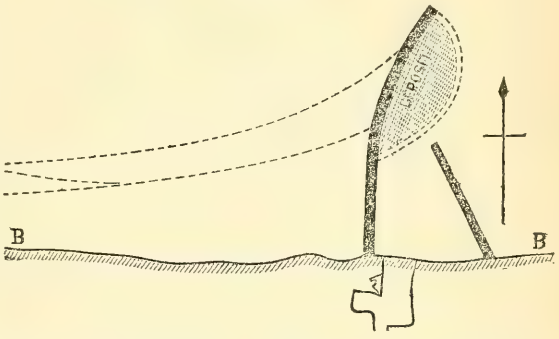
Port Said to the Red Sea being of secondary importance.

I have before said that the advance of the land seaward is about 75 yards a year at the bottom, and 50 yards at the surface, and the slope of the shore seaward is about 1 in 300. That is, to have six fathoms of water at the end of the breakwater, it must extend beyond the dry land portion about two miles; and, allowing these two miles a deep channel, at least 100 yards wide will have to be kept open. The question is: Will not dredging out end of the breakwater on the western side for a short distance, and even a deep hole scooped out at the extreme end, yet the current will sweep round the point, and deposit the mud and sand along the east side, as shown in Fig. 2. And it will be no easy matter to keep a deep channel through this deposit, where the depth is 30 ft., and the Mediterranean is not always a tranquil sea to work in.

What I therefore venture to suggest for consideration, is to extend the present breakwater, not in a north-easterly direction, but in a north-westerly one, running it out, as a sailor would say, in the teeth of the prevalent wind, or at an angle of 45 degs. with the coast, and for every 3 ft. of additional length there would be about 2 ft. of "offing;" thus any heavy material which may travel along the coast by the oblique action of the waves must come to rest, for it would have on reaching the breakwater to travel out to sea in the opposite direction to wind and waves, which is not likely to occur. By this modification it appears to me that there would be a great deposit all along the sea face of the Delta of the Nile, which in the course of centuries may affect the present geography of Egypt along the sea coast, but is a matter which may safely be left to the Duke of Suez's great-grand-children, to consider. Our present question is: Would this arrangement more perfectly stop the mud and sand brought down, by the Nile turning the end of the breakwater, and thus closing up the entrance to Port Said?—and this I believe it would, though some silt would still find its way between the blocks of Beton, and even round the end of the breakwater. But this channel to a depth of five fathoms (30 ft.) be a very expensive operation, and is there no way by which this may be avoided?

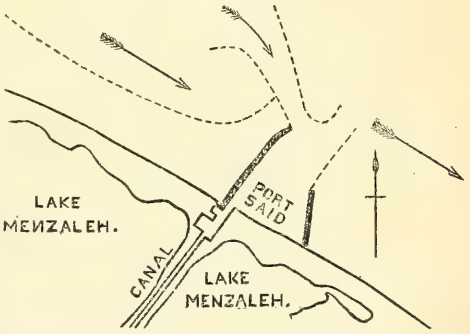
It has been proposed, I believe, to slightly change the direction of the breakwater hereafter, bending the outer portion in a more easterly direction, when it is supposed it will give a set to the current seaward, and deposit the silt in deep water. My experience of spurs on our river leads me to doubt this, and though there may be deep water along the outer

Fig. 2.



as this silt, as has been already said, is much finer or lighter than the land on the western side, it would be all the more easily affected by scour; so that the question is: How is this scouring power to be obtained? By another breakwater placed in a slanting direction, say at an angle of 60 deg. with the coast, a funnel-shaped channel would be obtained, as shown in No. 3.

Fig. 3.



Sketch of proposed new breakwaters shown by dotted lines. The arrows show direction of currents.

By such an arrangement I believe a sufficient scour may be obtained so as to keep a deep channel along the inner surface of the outer breakwater and that

it would only deposit a comparatively small quantity within the present harbor, carrying most of it away eastward to be deposited either out at sea in deep water, or behind the eastern harbor breakwater, where it can do no harm ; another advantage is that this plan admits of two ways for a ship to enter and leave the harbor ; a very important point for ships with the wind blowing on to the coast.

Having, I hope with sufficient clearness, explained my views with respect to Port Said, before speaking of the canal itself I may make a few remarks about the Suez end of the canal. Here at spring tides there is a rise and fall of 5 ft., and 3 ft. at neap tides, while at Port Said the rise and fall is only 9 in., though during strong gales the Mediterranean rises 18 in. The level of the two seas may be taken as identical, for by the last series of levels the difference was found to be only 3 in., the Mediterranean sea being the higher of the two.

Up to the time of my leaving Suez, no observations had been taken to determine with any great accuracy the velocity of the tides in and out of the canal at Suez, but it had been observed that there is a slight flow of water through the canal northwards from the Red Sea to the Mediterranean; but that it is very slight I can testify, for on one of the occasions when we dropped anchor in the small steamer going up the canal (we never did so coming down), I dropped crumbs of bread into the water, to try and discover if there was any current, and though I could perceive the bread sinking 2 or 3 ft. below the surface, yet I could not perceive any current up or down the canal. That there is a slight current northward I believe, and the question is how to account for it. The tidal wave passes Suez at a considerable velocity, and reaches the Bitter Lake probably before high water at Suez, so there is a regular stream into this lake.

The momentum thus given to the water will keep a stream of water pouring into the lake long after high water at Suez; for the area of the lake being several square miles, the rise in it will be little, comparatively speaking. As soon, however as it does rise, there must be a similar flow northward through the canal into Lake Timsah, which will slightly raise its level; and, again, if this level be thus raised above the main level of the Mediterranean, a similar action will take place here also, and water will flow northward; very slight, indeed, but enough to prevent it being quite stagnant.

Again, with the ebb tide, the rise of the level water in the Bitter Lake being so little, and it being upwards of 15 miles from the Red Sea, connected by a narrow canal, the few inches rise can have but little effect in causing a flow out of the lake southwards between half ebb and half flood; so that the outflow southwards must be much less than the inflow northwards; for every one who has observed the time of high and low water, and the time of the turning of the tide, must know that owing to the momentum the current has attained, the water begins to rise or fall some time before the tide turns in mid-channel.

Now, as the rise and fall in the Red Sea is 5 ft., the rush of the tidal wave up the canal northwards must be much greater than can possibly be attained by a slight rise of probably a few inches, and the extra momentum thus attained by the flood must take a considerable time to be overcome by the outflow back from the Bitter Lake—consequently the direction of the ebb must be shorter and less rapid; so the conclusion I thus arrive at is, that the average level of the Bitter Lake now, will probably be found to be somewhat higher than that of the Red Sea, even though there is a loss by evaporation.

It is thus I would venture to explain why there should be a flow northward up the canal from the Red Sea into the Mediterranean, but I hope shortly to be able to forward a note on the experiments now being made, which the officer in charge at Suez kindly promised to furnish me with. However, it has been generally observed that the flood tide at Suez up the canal is considerable, in comparison with the ebb. Be it owing to causes now given, or evaporation, or probably both combined, the effect on the canal channel will be to widen or deepen it at the Suez end; and unless the sides be protected it may become, in time, funnel-shaped like the mouths of all tidal rivers; so I think this should be guarded against, and rather deepen than widen the channel, for the transporting power of water decreases as the depth increases, it is believed ; and, therefore,

if this be true, less silt will be brought up the canal into the Bitter Lake. This, however, appears to be more a question of interest rather than importance; but in the case of the tendency to silting up of the mouth of the harbor of Port Said, it is quite another matter, and should be most carefully considered. I believe, however, that it will not become a pressing question for these next ten years, so that there is plenty of time, and before it arrives there will be, I believe, plenty of funds to meet the difficulty.

Having thus fully gone into the questions connected with the two extremities of the canal, I fear it would occupy too much time to describe the manner in which the breakwater is made of blocks of Beton, though it was fully explained to me, but which has already been described in several works, so I content myself by sending a specimen of the Beton made for the Port Said breakwater.

Regarding the canal itself there is no necessity to say much, for in an engineering point of view, it is simply a great ditch, hardly exceeding the Ganges Canal in cross-sectional area at some parts, and much less than it as to length. Any one who has seen the deep digging at the Synabas ridge at the 12th mile of the Ganges Canal, and the Purean Kullea one 5 miles further down, before the slopes were dressed off, can form a pretty correct conception of what the appearance of the Suez Canal is in deep digging, with this difference only, that we had clay where in Egypt they had chiefly sand. In opening the Suez Canal for traffic before the slopes were dressed, I think the Canal authorities showed great sense, for such a work looks much more imposing before than after the slopes are dressed.

As an engineering work the difficulties to be overcome were little in comparison to those on the Ganges Canal, where so many mountain torrents had to be crossed, and a channel had to be dug, and regulated by falls for a running stream, not a still water one; while on the Suez Canal there are neither locks, bridges, nor falls, and all these difficulties may have been said to have been overcome when they got fresh water, and the dredges were set to work, for then it was only a question of time and money.

It is not necessary for me to say anything about the dredges, and how they worked, but I will pass them by as the French Engineer did, who had been describing to me the process of making Beton, when he said "that is the steam engine which drove the works, but there is no need wasting time looking at it."

The two difficulties, I may say the enormous difficulties, the Suez Canal authorities had to overcome, were the organization of labor and the want of fresh water. Any one who has had 5,000 or 6,000 workmen to keep in order out in India can but form a slight idea of the difficulties of collecting people of all nations, Europe, Asia, and Africa, and organizing them into efficient laborers; but this was effected by the same process which never fails in India, namely, paying one and all for the actual work done.

As to the want of fresh water I shall simply mention that at one time the chief engineer had, he told me, three thousand camels employed bringing to the works the necessaries of life; so I need say no more as to the difficulties at starting; any one who has ever been exposed to a burning sun, and short of water, can imagine the rest. So I shall pass on to the question of drift sand.

That this has and will cause trouble and inconvenience there can be no doubt, but I look on it more as a "bugbear" than anything else. That sand in large quantities is moved by the wind, and will be blown into the canal, no one will dispute; but when the remains of canals made thousands of years ago are to be found, surely the Suez Canal is not going to disappear all at once by a dust storm; but this also may be overcome, of which more hereafter.

The next difficulty raised is the silt deposit in the canal. It has been already shown that there is no current to speak of in the canal, except at the Suez end, so the mischief is confined to the last 15 miles of the canal, and till I get a report of the observations that are now being taken, I cannot speak with any certainty as to the velocity or scour along this portion, but from what I observed, I do not anticipate much difficulty even in this short distance.

A very important question, which, though it may not be seriously entertained now, will most probably be brought

forward ere long—namely, as the level of the sweet water canal at Ismailia is several feet above that of the Timsah Lake, could not more water be taken from the Nile to fill the lake and the canal to a higher level for 10 miles on the south side, and some 7 miles on the north, and have a set of locks at both ends to descend again to the levels of Lake Ballah and the Bitter Lakes?

Ship-masters may say there will be delay in passing through the locks, but this could hardly occupy half an hour, and it has been shown that there are from 2 to 4 hours at least to spare; so time can be of no moment, for under any circumstances it will take two days to pass from Suez to Port Said except in cases of emergency seldom likely to occur. There will practically therefore be no delay by having locks with the centre portion fresh water, but possibly a saving of time, for ships could while at anchor get a supply of fresh water of the Nile, and bringing the ships into a fresh water lake will most certainly kill the marine animals attached to the ships' bottoms; thus, instead of a loss of time, there probably will be a great gain by the ships leaving the canal with comparatively clean bottoms.

This, however, is not the advantage I look forward to, but to the reclamation of the desert by irrigation; which is not a matter of doubt but certainty, for there are proofs existing to show that canals were made near Ismailia by the ancient Egyptians; so we would only be carrying out what was formerly done several thousand years ago, and the gardens of Ismailia show that only water is required to make the soil most fertile. With Lake Timsah converted into a fresh water lake, which formerly it most probably was (as "Timsah" signifies crocodile, and these creatures live in fresh or brackish water), there could be no difficulty in running branch canals from above the locks, so that all the ground round the Bitter Lakes on both sides, as well as that of Lake Ballah, could be reclaimed, and not only would the Egyptians be enriched, but the Canal Company need no longer fear sand storms. This can no doubt be still carried out by siphons and pass the fresh water under the salt water canal, but the expense would be considerable.

To carry out all that appears necessary is to widen the present fresh water canal from Ismailia to the Nile, and probably a permanent weir or anicut with regulators would be required to be thrown across the Nile near Cairo, where stone is to be had in any quantity. Though this project may at first sight appear too great, yet when it is contemplated to construct similar works across such rivers as the Ganges and the Sutlej, where no stone exists, but all must be made of bricks, the proposal does not appear so problematical as some may at first sight think, and I believe it could be carried out at a comparatively little cost.

With a weir and regulators at Cairo, a complete command could be had over the supply, so that the whole irrigation system of Egypt could be vastly improved; for there would be no waiting till the Nile rose, as has been the case, but the water could be held up to the required level at all seasons. The work in fact would be similar to the Godavery anicut in Madras, only on a somewhat smaller scale as to length of work.

These permanent works would have to be constructed by Government, probably by contract, and would to all intents and purposes be a State work, chargeable to the whole community, for all would be benefited more or less; so unpaid labor had better not be employed on such an undertaking, for skilled labor would be required.

In widening the present fresh water canal, however, the ancient laws of Egypt could be put in force with advantage, as the laborers who perform this work would have the first claim on the land to be recovered from the desert, so they would be remunerated by receiving title-deeds to plots of land according to the work performed; thus all would be done without putting the Government or the Suez Canal Company to any extra outlay, while it would be quite in the spirit of the ancient Egyptian laws, to which I referred in my other report on Egyptian irrigation.

In 1865, before I knew anything about these ancient Egyptian laws, I suggested in my report on the irrigation of the Rechna Doab, that to induce people to come and work on the proposed canal at low rates, a promise of land should be given to the laborers according to the actual work done by them, and I stated my belief that such an inducement would

draw crowds of laborers, who would gladly work at comparatively low rates under such a promise. What I have since learnt while passing through Egypt confirms me in this opinion, and I think it should be tried on all new canals where large tracts of waste land are to be reclaimed.

Viewing the matter in this light, it appears to me that making Lake Timsah fresh water would be adding wealth to the Egyptians, while probably also it would be a saving to the shareholders of the Suez Canal. Widening and deepening the canal, as some think is necessary, must be very expensive in deep cutting, if not a difficult and tedious process where the belt of rock crosses the line, while to build two locks at either end before entering the Ballah and Bitter Lakes is a simple affair; so both in an engineering and also in an economical point of view this suggestion appears worthy of consideration; but be it adopted or not, I for my part have little doubt that the Suez Canal will prove a blessing to the whole world, to India in particular, and will ere long enhance Indian revenues several millions yearly by the enlargement of commerce with the West.

We all know, by experience, that with canals in India there is a time of infancy as well as manhood, and that they take several years before they become remunerative. Possibly such may be the lot of the Suez Canal, and that for a few years to come the transit dues will hardly cover the working expenses, in which case there will be a great loss to the shareholders, and a greater outcry; but as the canal is now admitted, as far as it goes, to have been a success, and that it will ultimately prove to be a general benefit to the world, let it not be said that the nations of Europe and Asia allowed the loss to fall on the pioneers who constructed this great work.

That the work has been honestly executed and paid for, I have every reason to believe, for on examining the mode adopted of periodically making sections of the work done and measuring up the whole each time, deducting former progress, shows that it would be next to impossible to use fraudulent measurements; for not only the contractors, but the workmen were paid by these measurements, so that if, at any time, too great a progress was given and afterwards this excess was deducted, the workmen who were last employed would not be long in pointing out that they had been defrauded, and if this was customary and these complaints were not heeded, the work would have soon come to a close. The fact, therefore, that the workmen agreed to be paid by such a system, where the men employed could not probably be always the same, proves to me that the utmost care must have been taken to have correct measurements; in other words, quantities can without difficulty be submitted fraudulently; with measurements the fraud is most liable to detection.

Believing therefore that the expenditure has been honestly accounted for, and bearing in mind the enormous difficulties that have had to be overcome, and the benefits likely to accrue, I think that an international guarantee against loss to the shareholders should be given, India bearing its share of this responsibility; or if need be, that a sum of £25,000,000 should be subscribed, and that the £16,500,000 expended, plus the interest on capital from the day of official opening to the day of settlement, should be paid to the shareholders.

With the balance remaining over, the canal could be put in complete working order, and light-houses built in the Red Sea, while by such an arrangement the transit dues need only be nominal—only sufficient to cover working expenses—thus, the returns to each subscribing power would arise from individual sources rather than direct taxes on ships passing through the canal.

In advocating these views, I do so without having any personal interest in the matter, or knowing any one who has money invested, but simply from a feeling of justice and gratitude all must feel to those who have conferred such a great benefit on the civilized world.

It is intended to have 16,000 tons of iron for the Northern Pacific Railroad at Duluth, before navigation closes. From Erie, Ward's steamers will take 5,000 tons, and sailing vessels as much. Part of this has gone forward. The Winslow line is to bring 3,500 tons from Cleveland. This will be enough for about 200 miles of road.

METEOROLOGICAL TABLE OF TEMPERATURE, ETC., FOR TWENTY-FIVE YEARS.

By Prof ORAN W. MORRIS, New York City.

—	Mean Temperature for 25 Yrs.	Highest, and the Month.	Lowest, and the Month.	Warmest Day of the Year, and Sum.	Coldest Day, etc.	Average of the Seasons.				Quantity of Rain.	Average Rain.	Greatest Rain in One Month.	Least Rain in One Month.	Rainy and Snowy Days.
						Spring.	Summer.	Autumn.	Winter.					
	Deg.	Deg.	Deg.	Deg.	Deg.	Deg.	Deg.	Deg.	Deg.	In.	In.	In.	In.	
1845....	51.450	90.0 July.....	6 Feb.....	June 9 78.50	Feb. 1 6.00	47.160	70.110	56.480	31.850	35 350	2.862	4.93	1.240	113
1846....	50.560	91 "	3 "	July 11 84.50	Jan. 28 10.25	47.102	71.230	55.306	28.260	47.067	3.975	8.940 Feb...	0.870 Sept.	117
1847....	50 493	88 June & July	11 Jan.....	" 19 85.00	" 22 15.00	45.885	70.221	53.194	30.960	42.44	3.858	7.51 Sept..	0.98 Apl...	135
1848....	51.092	89 June.....	3 "	June 17 81.50	" 10 10.25	48.899	70.768	50.848	37.026	41.741	3.794	7.16 June..	1.87 Feb...	114
1849....	49.582	92 July.....	− 4 "	July 13 87.50	" 11 3.75	46.116	70.064	54.491	29.536	35.546	2.966	5.98 Oct...	0.65 Jan...	130
1850....	51.765	90 "	11 Feb.....	" 30 83.875	Feb. 5 14.625	45.792	72.607	54.727	44.840	50.329	4.194	6 659 May..	1.965 Nov..	149
1851....	51.974	92.3 June.....	7.8 Jan.....	June 30 82.700	Jan. 30 10.36	49.620	72.690	55 800	51.070	45.844	3.820	6.442 Apl...	1.282 Sept..	139
1852....	51.400	93 July.....	− 2 "	.....	.....	46.920	73.190	53.670	31.840	43.840	3.653	6.200 Aug..	2.06 Oct...	126
1853....	52.240	98.2 June.....	9 "	.....	.....	49.320	72.500	54.240	32.900	52.641	4.386	5.80 May..	1.04 Dec...	99
1854....	51.682	95 July	3 Dec.....	July 20 86.66	Dec. 20 10.00	48.220	73.867	55.320	30.174	42.435	3.536	10.11 Apl...	1.06 Aug..	126
1855....	51.066	93.5 "	− 8 Feb...	" 18 87.40	Feb. 6 0.50	47.357	70.912	55.305	27.831	52.910	4.419	7.37 Oct...	1.51 Sept..	131
1856....	50.536	95 "	− 5 Jan.....	" 19 88.43	Jan. 9 0.73	45.633	73.648	55 563	28.053	40.502	3.375	6.73 Aug..	0.66 Feb...	105
1857....	52.199	90 Aug.....	0 "	Aug. 14 85.20	" 18 2.53	47.570	71.880	55 852	31.320	53.880	4.490	9.05 Apl...	1.30 Nov..	135
1858....	53.161	93.5 June.....	− 3 Feb....	June 26 87.80	Mar. 5 11.16	48.293	74.647	55.305	32.571	51.070	4.256	6.42 June..	1.47 Mar..	123
1859....	53 120	96.5 July.....	− 8 Jan.....	July 11 85.16	Jan. 10 2.90	52.235	72.673	54 411	34.382	55.66	4.640	8.21 Mar..	1.57 May..	163
1860....	52.884	89 "	− 7.7 Feb....	June 30 83.26	Feb. 2 7.43	50.251	73.170	55.919	32.046	45.17	3.760	7.57 Nov..	1.43 June..	167
1861....	53.870	92 Aug.....	− 3.1 "	July 9 84.90	" 8 3.06	49.456	73.063	57.500	33.783	54.65	4.554	8.09 " ..	1.73 Dec...	144
1862....	53.255	95.4 "	8 Dec.....	Aug. 9 88.63	Dec. 20 13.10	50.750	72.425	57.883	33.706	53.97	4.497	9.03 June..	1.91 " ..	169
1863....	54.239	95 "	6 Feb....	" 3 89.40	Feb. 4 8.33	49.130	75.454	56.630	36.082	57.03	4.752	8.60 July..	1.05 Sept..	157
1864....	55.410	97 June.....	8 "	June 26 91.26	" 10 10.00	51.900	76 936	55.716	36.010	47.61	3.969	5 90 Dec...	2.04 Feb...	157
1865....	55.508	95 July.....	−13 Dec.....	July 28 86.56	Jan. 27 13.43	54.389	77.396	57.469	32.139	62.98	5.248	10.42 June..	2.23 Aug..	144
1866....	52.125	98.8 "	−13 Jan.....	" 17 90.93	" 8 2.33	49.613	72.166	54.856	34.280	52.23	4.350	10.09 Feb...	1.67 July..	150
1867....	49.887	91 June.....	4 "	June 30 87.86	Dec. 13 8.23	45.290	70.926	54.186	30.360	54.655	4.554	10.18 June..	0.78 Sept.	168
1868....	48.669	92 July.....	− 0.5 Feb....	July 16 84.83	Feb. 3 6.30	44.908	71.909	52.156	25.603	64.03	5 336	9.60 Sept..	2.01 Oct...	155
1869....	51.503	93 Aug.....	8.5 March..	Aug. 20 84.66	Jan. 22 16.83	47.329	71.844	53.441	31.257	55.535	4.628	7.29 Feb...	1.57 Apl..	171
Mean...	51.987	....	.....	....	.....	48 341	72.652	54.811	32.314	49.563	4.188	.....	.....	139.5

The Table of temperature presented above, embraces a statement of the observations made during a series of 25 years, in the city of New York; and comprises the annual means; the maximum and minimum; the warmest and coldest days; the means of the seasons; the quantity of water from rain and melted snow; the number of days on which rain or snow fell; and some other phenomena.

The average temperature for the 25 years is 51.987 deg.; the series shows but little variation from the average. The first 12 years, with the single exception of 1853, are all below the average; the next 10 years are above, and the 3 last below—1868 being the lowest of the series, 48.669 deg., or 3.318 deg. below the normal; 1865 is the highest, 55.508 deg., or 3.521 deg. above the normal, and 6.839 deg. higher than 1868.

The maximum, at 2 P. M. was 98.8 deg., July 17th, 1866; this was 49.033 deg. above the normal (at 3 P. M. of this day it was 101.02 deg. for a very short time). The minimum was 13 deg. below zero, twice—once Dec. 8th, 1865, the other, Jan. 8th, 1866. It was above zero, in 14 years; at, or below, in 11 years—5 times in Jan. 5 times in Feb. and once, in Dec.

The maxima of the series are quite as uniform as the means, varying only about 11 deg., *i. e.* from 88 deg. to 98.8 deg.; the minima varied from 11 deg. above to 13 deg. below, a range of 24 deg. In 1866, the maximum and minimum both occur, showing a range of 111.8 deg.; besides being the warmest year of the series.

The warmest day, June 26th, 1864, was 91.26 deg. above zero; the coldest day, Jan. 8th, 1866, was 2.33 deg. below—a range of 93.59 deg., with an interval of $1\frac{1}{2}$ years. The warmest days in each year were very uniform, only 1 being below 80 deg.; the coldest days ranged from 2.33 deg. below zero, to 16.83 deg. above, having an interval of nearly 3 years between.

The different seasons are each quite uniform also. The means for the spring was 48.341. Of these, 13 are below the mean, and 12 above it. The warmest spring was in 1865, 54.389 deg.—6.048 deg. above the mean; the coldest, was in 1868, 44.908 deg.—3.633 deg. below it, a range of 9.481 deg. The mean for the summer was 72.652 deg.; of these, 13 years were below, and 12 above, the mean. The warmest was in 1865, 77.396 deg.—4.744 deg. above the mean; the coldest in 1845, 70.11 deg., 2.542 deg. below—a range of 7.268 deg. The mean for autumn, 54.811 deg., gives 8 years below the mean and 17 above; the warmest was in 1862, 57.883 deg.—3.072 deg. above the mean; the coldest in 1848, 50.848 deg.—3.963 deg. below a range of 7.035 deg. The mean for winter was 32.314 deg., with 13 years below it, and 12 above; the warmest was in 1848, 37.026 deg.—4.712 deg. above the mean; the coldest in 1868, 25.603 deg., 6.711 deg. below it, a range of 11.423 deg. In the series for spring there were only 5 years above 50 deg. In the series for summer, all were above 70 deg. In the autumnal series, they were all above 50 deg., and in that of winter there were 5 below 30 deg. Some months, in each season, were much warmer, and others much colder than the corresponding months in other years.

The average quantity of water from rain and melted snow was 49.563 in.; 15 of the years were above the mean, and 10 below. The greatest quantity in any one year, was in 1868, 64,030 in., 14,467 in. above the mean; the least was in 1845, 35,370 in., 14,213 in. below a range, in quantity, of 26,68 in. The average quantity per month was 4,188 in.

The difference not only in quantity in different years and months, but also in the number of days on which rain or snow fell, is suggestive, as indicating the necessity for a careful and scientific system of sewerage to preserve the health of cities and towns.

The average number of days on which rain or snow fell was 139.5 days. Of these, 13 years were below the mean, and 12 years above. The largest number of days in any one year was 171, in 1869, and the smallest was 99, in 1853.

In this series for New York city, the coldest weather occurred 4 times in January, 10 times in February, 3 times in December, and once in March. The warmest weather occurred 13 times in July, 7 times in June, 4 times in August, and once in both June and July.

The Spanish foot is equivalent to 11.03 English in.; the Prussian, 12.36; Austrian, 12.45. Russian, 13.75; Portuguese, 12.96.

IRON AND STEEL NOTES.

STATEMENT of the export of rails from Great Britain, compiled from official returns published by authority of the House of Commons:

COUNTRIES.	Month ending Oct. 31. 1868. Tons.*	1869. Tons.	1870. Tons.
AMERICA.			
United States	18,723	18,743	28,219
British	302	260	4,793
Cuba	644	....	10
Brazil	195	1,091	281
Chili	10	115	869
Peru	1,087	....	349
EUROPE.			
Russia	30,627	50,607	10,196
Sweden	14	505	474
Prussia	466	3,508	2,603
Illyria, Croatia, and Dalmatia	2,362	553	2,578
France	41	315	20
Holland	547	203	252
Spain and Canaries	1,848	613	936
ASIA.			
British India	2,742	10,320	8,658
Australia	422	2,004	417
AFRICA.			
Egypt	....	26	102
OTHER COUNTRIES.	3,665	7,581	9,016
Total	63,695	96,444	69,773
Pig Iron to U. S.	7,435	13,668	12,875

COUNTRIES.	Ten Months ending Oct. 31. 1868. Tons.	1869. Tons.	1870. Tons.
AMERICA.			
United States	228,091	262,829	341,629
British	15,535	23,929	34,705
Cuba	2,662	885	3,199
Brazil	2,171	2,913	3,232
Chili	1,450	2,762	13,849
Peru	3,159	18,720	13,680
EUROPE.			
Russia	100,554	247,278	204,005
Sweden	1,596	3,938	2,595
Prussia	5,721	14,910	41,912
Illyria, Croatia, and Dalmatia	10,498	22,317	35,495
France	161	4,235	362
Holland	21,113	10,078	15,212
Spain and Canaries	7,392	11,609	10,880
ASIA.			
British India	61,333	76,200	140,845
Australia	8,131	19,842	7,798
AFRICA			
Egypt	10,512	6,051	2,116
OTHER COUNTRIES.	29,889	65,123	60,477
Total	509,968	793,619	931,991
Pig Iron to U. S.	75,504	118,297	97,586

* Tons in all cases 2,000 lbs.

—*Bulletin of American Iron and Steel Association.*

IRON TRADE ON THE CONTINENT.—The Anglo-Russian difficulty not having become more threatening up to this present writing—although it is impossible to say what a few hours may involve one way or the other—Belgian industrials have somewhat regained confidence, and have begun to hope for a peaceful solution. At any rate, they greatly desire it, as a war between England and Russia would be a rude shock to Belgian metallurgical industry. The Belgian blast furnaces are still disposing of their production tolerably well. The imports of iron minerals into Belgium, in August, amounted to 38,357 tons, against 57,461 tons in August, 1869; in the first eight months of this year they footed up to 424,130 tons, against 376,924 tons in August, 1869. The total imports of iron of all kinds into Belgium in August, 1870, amounted to 3,517 tons against 4 059 tons in August, 1869; and in the first eight months of this year to 65,543 tons, against 37,235 tons in the corresponding period of 1869. The exports of minerals from Belgium amounted in August to 13,242 tons, against 10,294 tons in August, 1869; and in the first eight months of this year to 127,396 tons, against 108,525 tons in the corresponding period of 1869. The exports of rails from Belgium declined in August to 7,132 tons, against 19,486 tons in August, 1869. The rail exports of the first eight months of this year were 93,889 tons, against 103,746 tons in the corresponding period of 1869. The exports of rails to the Zollverein, France, and Spain, show a marked increase; those to Russia, the Low Countries, Turkey, Italy and the United States exhibit a sensible decrease. The annexed table shows the exports of iron of all descriptions from Belgium during the first eight months of 1870 and 1869:—

Destination.	1870.	1869.
Russia ..... Tons	45,611	55,097
Sweden and Norway	1,850	732
Denmark	75	598
Zollverein	34,901	22,507
Hanse Towns	2,609	3,162
Low Countries	16,198	18,665
England	8,481	8,347
France	28,067	27,295
Spain	2,917	353
Italy	6,670	13,493
Switzerland	2,809	2,286
Austria	1,197	1,320
Roman States	35	28
Turkey	16,738	27,429
Egypt	1,493	30
United States	6,954	10,313
Cuba and Porto Rico	1,337	691
Brazil	362	663
Rio de la Plata	111	440
Chili and Peru	273	361
Other destinations	130	364
Total	177,818	197,114

In these totals August in each year figured for 15,447 and 31,605 tons respectively. Makers of railway plant in Belgium were recently promised by the Belgian Minister of Public Works an order for 520 trucks and 30 locomotives, but they have not yet actually received this commission.

PRICES OF STEEL RAILS.—The correspondent of a leading English journal, writing from Birmingham, says that in that city conspicuous men-

tion is being made of the rapid advance in the price of steel rails. "I have," says he, "often spoken of the scarcity of ore that, as far as is yet known, can alone be utilized to make Bessemer iron. That scarcity is being increasingly felt; and as the manufacture of steel by the Bessemer process is concentrated in few and powerful hands, the natural tendency is towards higher prices. Steel rails are now quoted at £11 5s. a ton—a price considerably higher than that at which they stood when a high royalty had to be paid to the patentee. These facts are giving rise to much investigation by geologists of localities anywhere supposed to possess the much-coveted mineral; and speculators here are looking for such property as a desirable means of investment."—*American Artisan.*

VARNISH FOR IRON.—The following is a method given by M. Weisskopf, of producing upon iron a durable black shining varnish:

"Take oil of turpentine, add to it, drop by drop, and while stirring, strong sulphuric acid, until a syrupy precipitate is quite formed, and no more of it is produced on further addition of a drop of acid. The liquid is now repeatedly washed with water, every time refreshed after a good stirring, until the water does not exhibit any more acid reaction on being tested with the blue litmus paper. The precipitate is next brought upon a cloth filter, and after all the water has run off, the syrupy mass is fit for use. This thickish magma is painted over the iron with a brush; if it happens to be too stiff, it is previously diluted with some oil of turpentine. Immediately after the iron has been so painted, the paint is burnt in by a gentle heat; after cooling, the black surface is rubbed over with a piece of woolen stuff dipped in and moistened with linseed oil. According to the author, this varnish is not a simple covering of the surface, but it is chemically combined with the metal, and does not, therefore, wear or peel off, as other paints or varnishes do from iron."—*Journal of Applied Chemistry.*

ELECTRO DEPOSITS OF IRON.—Printers have for a long time complained of the fragile nature of the copper stereotypes, so easily damaged by a few irregularities in the paper, or through dust coming in contact with them while printing.

E. Klein, a Russian mining engineer, has succeeded in obtaining iron electro deposits suitable for printers, offering the great advantages of cheapness and durability. The samples produced by Mr. Klein give us assurance that this discovery will find its application in different manufacturing processes where the copper electro deposits now have such importance.

In 1867, M. Feuquieres exhibited at the "Exposition Universelle," samples of iron electro deposits, but the process of Mr. Klein differs entirely from the one used by Feuquieres.

Klein, in order to increase the solubility of the iron anode, used a similar composition to the one employed by Jacobi, in 1856, for the electro-chemical decomposition of the silver baths. As a proved fact, the quality of the iron electro deposits depends entirely on the more or less solubility of the anode, the most soluble yielding the best results. It was at first thought that in increasing the surface of this anode it would bring a better result, but the result of the experiment was not successful. Mr. Klein then combined copper anode with an iron, or, according to Jacobi's experiments, replaced the copper by graphite or retort coke. The effects of such a combination can be explained as follows:

The negative metal combined with the iron in the bath has a double action; it acts as catode against the iron, and as anode by its combination with the positive pole of the battery yielding the principal electrical current. Then, at the surface of this electrode, hydrogen and oxygen are evolved simultaneously; these, in a nascent state, combine in proportions to form water. The excess of hydrogen is set free or produces a polarization of the electrode; if the oxygen is more abundant and if the electrode is made from an inoxidable body, as the retort coke (graphite), there will also be gas evolved and a small polarization, but if the electrode is oxidable, as for example the copper, it will then be oxidized and dissolved. —*Journal of Applied Chemistry.*

RAILWAY NOTES.

IMPORTANT RAILROAD CASE.—In the suit in the Supreme Court brought by Frederica Klumbach against the New York Central Railroad Company, relating to the buffer irons and cheek blocks between freight cars, whereby her son, a brakesman, was killed, a verdict has been given against the Company for $3,500.

Without reference to the merits or the important legal questions involved in this particular case, it is to be hoped that it will be the means of leading the directors of railroad companies to look for themselves whether their arrangements for the coupling of freight cars are such as ordinary humanity requires, and whether the cheek blocks on the end of freight cars project far enough to preserve the lives of brakesmen whenever the buffer irons give way or prove defective.

Many human beings have been crushed to death between freight cars. A measurement of cheek blocks on the New York Central freight cars shows that in some instances these cheek blocks project only 3½ in., sometimes only 4½ in., and sometimes only 6 in. Thus, if the buffer irons of opposite cars should be broken and the cheek blocks come together, there would in some instances be for the brakesman a space of only 7 in., sometimes 9 in., and sometimes only 12 in. Now, according to the testimony of experienced brakesmen, as well as medical testimony, 16 in. is the very least space into which a brakesman should be asked to stand, especially as the freight cars frequently come together with great force.

At the trifling expense of one or two dollars on each car, each cheek block could be made to project 8 in., and thus secure for the brakesman a clear space of 16 in., even if both buffer irons were broken off or driven back under the cheek blocks. This ought to be done with each new freight car, and with the old ones whenever brought into the shop for repairs; and thus in one or two years every freight car on the road would be so constructed as to save the lives of brakesmen, and save the Company from the appearance of needless cruelty and from expensive lawsuits.

Experienced brakesmen think the danger attending the coupling of freight cars is unnecessarily increased by allowing the ends of the side sills to project beyond the cross sills, into the space through which brakesmen must pass when going in between

cars to couple them, or when attempting to come out.

From October 1, 1868, to October 1, 1869, 41 employees on the railroads in this State are reported as injured or killed while coupling cars. Of this number, 27 are reported on the Erie Railroad, 4 on the Buffalo & Erie, 3 on the New York Central, and 3 on the Hudson River Railroad.—*Exchange.*

A Thirty-inch Gauge Railway in Ohio.—The Toledo "Commercial" having stated that the Piqua, St. Mary's & Celina R. Co. had been incorporated on a capital basis of $400,000, to build between Piqua and Celina, through Miami, Shelby, Auglaize and Mercer counties, Ohio, about 44 miles, a Piqua correspondent gives us the details of the scheme.

The country along the line is very populous and productive, and the question of an outlet by railway has long been agitated. But the Miami & Erie canal passes through it already; and while inadequate to the wants of the country, there is scarcely warrant for the construction of an expensive road. Last winter, the plan of a narrow-gauge road was proposed and discussed,—costing, fully equipped, less than half a million of dollars, in place of one of the ordinary gauge costing a million and a half. The design is identical with that of the Welsh railways, which have been so often described in engineering journals of late. A road of this kind for transporting coal is already in operation (the only one in this country as yet,) between Akron and Massillon, Ohio. A system of narrow-gauge railways is also projected from Toronto, Canada, as feeders to the wide-gauge roads now centring there. We learn that parties interested in the proposed Buffalo & Springville Road are now examining the Canada system, with a view to the adoption of the narrow gauge. The Kansas & Denver Pacific Companies also contemplate reaching the mining regions near Denver, and probably at no distant day penetrating the Great Mountain Parks, and perhaps passing over the entire range, by narrow-gauge roads costing only one-seventh as much as the present gauge, where the latter is practicable. In all these cases the data showing the entire practicability of these roads, and giving the cost of construction and operation are such as to reduce the prospects of any such enterprise to a certainty.

To return to the Ohio Road. The right of way is to be 15 ft. in place of 40 ft.; 20 lbs. instead of 56 lbs. iron will be required; the locomotives, weighing 6 tons instead of 30, will draw from 10 to 20 loaded freight cars, each having a capacity of 2½ tons; under freight and passenger cars alike (the latter seating 20 persons), four-wheel trucks will be placed; the ties will, of course, be nearer than on the wide gauge; while finally, on account of the lightness of car equipment, in comparison with capacity, and of the central position of the trucks, both higher gradients and sharper curves are practicable, greatly reducing cost of excavation and other important items of construction.

In the present instance, the route presents no engineering difficulties—Piqua, thence following the canal to Berlin; thence to Minster, Bremen, and St. Mary's, where it will leave the canal, and make Celina its Northern terminus.

The enterprise, which is to be begun in January, is in the hands of able and energetic citizens—among the corporators being Hon. J. F. McKinney, member of Congress elect; William Scott, one of the oldest citizens, and President of the Piqua National Bank; J. G. Young, Cashier of the same; Henry Flesh, a wealthy merchant of the city; Chas. C. Clute, an experienced railroad builder, of New York city.—*Chicago Railway Review.*

The Railway System of Europe.—The railways of Europe and America form systems by means of which the business circulation of nations is kept up. But the two systems differ very materially. The European system was devised with a full recognition of the public necessities and ultimate interests involved, while our own has, until quite recently, been a natural growth, controlled by no particular policy, and restrained by no governmental authority. Many of the European roads were either constructed by the Government, or under grants which allowed the authorities to retain control of them—Great Britain, we believe, being the only exception.

In France there were, according to the latest reports, over 9,000 miles of railroads in operation, all constructed since 1836, at an average cost of $125,000 a mile. They were built under the supervision of the Government, and were largely aided by Government loans. They are now leased to six great companies, for a term of ninety-nine years, and pay the Government ten per cent. of the gross receipts. At the end of the lease the roads revert absolutely to the Government, but meanwhile the mails are transported free, and troops and Government property at reduced rates. The rates to be charged the public by the roads for freight and passage are fixed in the leases, and are so profitable that the stock of the companies steadily commands a premium. From their yearly profits the companies are also obliged to put by a certain sum, which, at the end of the lease, is to be used to reimburse the shareholders for their original investment. This tends still further to give stability and public favor to the stocks.

Belgium has but 1,250 miles of railroad, constructed at an average cost of $91,500 a mile. These roads, like those of France, were constructed partly by the Government, and partly by companies which received their franchises on condition that their capital should be gradually refunded, with a liberal interest, and that thereupon the roads should revert to the State. At first the Belgian roads returned no profit, but of late years, by reason of increased business, they are paying the shareholders seven per cent. per annum. Prussia has 3,800 miles of railroad, costing $83,700 per mile. Of these lines about one-half are worked entirely by the Government, and the rest by companies under concessions very similar to those made in France. One feature of the Prussian system is peculiar. The Government will not permit the construction of competing lines, nor allow combinations between any two or more lines.

Austria has 3,700 miles of railroad, costing an average of $108,500 per mile, and constructed by companies under concessions by which the roads become the absolute property of the State at the end of ninety years; meanwhile the rate of fare and freight charges being regulated by the Government. The roads have proved profitable, and have paid dividends of seven per cent., which seems to satisfy the Austrian capitalists, even with the prospect of obliterating the principal at the end of ninety years.

The railway system of England has been built upon an entirely different plan from that of any of the continental powers, and with the exception of the stricter governmental control which has been exercised, it is not very different from our American system. The roads have been built by private companies, and without restriction as to competition. There are 14,247 miles of railway in Great Britain, representing an aggregate capital of $2,511,314,435. The peculiar feature of the system is, that although the roads were built by private enterprise and capital, and do an enormous and increasing business, they do not, in the majority of cases, pay any thing like remunerative dividends to the shareholders. Many of the principal lines have made no dividends for several years, and others make from 1 to 3 per cent. The London, Chatham and Dover, which cost $50,000,000, has never paid a dividend, nor even the interest on its first issue of bonds, and is now in the hands of a receiver. It seems strange to read, in the London "Railway News," that some of the roads are really in a flourishing condition, as compared with past years, and that they have declared dividends ranging from 4½ per cent. to 2 and 3 per cent.

The result in Great Britain is, that railroad investments have been almost total losses, and that the system has become so involved, and the stocks so depressed, that it has been seriously proposed that the Government should purchase all the lines at their actual market values, and run them in the public interest. The most sagacious railroad men in England express the opinion that ultimately this policy will be adopted, and that rates will then be put at a figure barely sufficient to defray the cost of maintaining and operating the roads. It will be seen that in all the Continental States such a policy is already provided for, and it seems probable that it will eventually become a general feature of the railway system in Europe.—*N. Y. Times.*

The Panama Railroad.—The statement of the directors of the Panama Railroad for the period down to the end of September shows the sound condition of the Company, though the line has suffered from a considerable decrease in traffic since the opening of the Transcontinental route through the United States. The gross earnings of the road for the 9 months ending September 30, were $955,218 collected, to which should be added 150,000, the estimated receipts of parts of August and September, the returns for which had not come to hand, making a total of $1,105,218. The working expenses amounted to $388,870, as against $784,071 in the corresponding period of 1869, leaving the net earnings $716,348. From this has to be deducted the subsidy to the Columbian Government, and the interest on the bonded debt, leaving net for the 9 months $340,860. The condition of the Company at the present time is as follows:—The total cost of the railway, including payment for extended contract, was $9,500,000, of which $7,000,000 is represented by share capital. There is no floating debt, and to meet the bonded debt, of which the greater part matures in 1867, a sinking fund has been provided, on account of which a sum of $1,189,404 has been up to the present invested—sufficient, with accumulations, to retire all the bonds at maturity. The assets of the Company consist of cash and realizable securities, $747,468, the fleet of steamers and sailing vessels valued at $800,000, and real estate in and around Panama, worth, at cost, $73,140. There are besides vacant lands on the Isthmus in its possession amounting to about 300,000 acres, the value of which it is difficult to estimate. At the usual meeting of the directors of this road, held on the 24th September last, the present condition of the Company in its altered state, consequent on the opening of the Pacific Railroads, was taken into consideration, and it was resolved to return to the system of semi-annual dividends instead of quarterly payments, which have been made since 1862. The alteration is rendered necessary by diminished revenue of the Company, which the directors ascribe to several obvious causes. 1. The diversion of the traffic to the Pacific lines. 2. Establishment of competing line of steamers to West Coast of South America. 3. The reduction in rates for passengers and freights. 4. The increase of percentage of working expenses, owing to the impossibility of curtailing them as rapidly as the traffic fell off; and lastly, the decline in premium on gold. The directors look forward to a more satisfactory result for the ensuing year, by working the line with the most rigid economy, from gradually increasing business to be anticipated from reduction of freights, which will enable them to compete with the Pacific roads, and from business which will probably accrue from the anticipated establishment of new steam communication between Germany and the Isthmus.—*The Railway News.*

The Honduras Railway.—We have from time to time announced in these pages the shipment of cargoes of materials to be used in the construction of the Honduras Interoceanic Railway, and the arrival of consignments of mahogany despatched by the Honduras Government for realization here in fulfilment of its obligations with regard to this undertaking. It is only by such notices that the public is as yet informed of the continued progress of this vast and important undertaking. The line has hitherto, from its competition with interests vested in the Panama route, been the subject of continual misrepresentation, and the Transatlantic journals particularly indulge continually in depreciatory remarks as to the progress already made and the prospects of the line when completed. Its keenest opponents, however, cannot consistently deny the many advantages which the Honduras Railway, when completed, will have. As a means of communication between the Atlantic and Pacific oceans, the route by it is considerably shorter both as regards Europe and the United States, than that by the Panama line, while it will open up large and valuable tracts of country. There can be no doubt whatever that the line, when opened, will show as good or better results than the Panama Railway, as there is sufficient business for both routes, and the Honduras Railway will possess the advantages of easily accessible ports, with deep water at both its termini. The difficulty that has hitherto existed in the prosecution of the line is the want of labor, which, it will be remembered, was encountered also in the construction of the Panama route; but great exertions are now being made to obtain the necessary supply. The work is divided into three sections. The first section runs from Puerto Caballos, on the Atlantic side, to a point in the interior, close to the seat of Government. A great portion of this is already completed, and a locomotive is running on it, and native labor is now being

procured to press forward its completion. All the rails, the engines, and a portion of the rolling stock necessary for the section have been shipped, and the remainder of the rolling stock is now ready for shipment. With regard to the second section, a very large staff has been sent out from this country to make the surveys, and this staff has been engaged upon the works for the last four months; while all the rails and materials for the line have been purchased, and a portion of them shipped. A staff of engineers has also been employed during the same time on the third section, and workmen were sent to the Bay of Fonseca in the beginning of last month, to commence operations at that point. More recently the contractors' agent and manager has sailed with a further staff, and the supplies of plant for this portion of the work are being sent rapidly forward. There is now little doubt that the whole of the work will be completed by the end of next year—the time specified, and in the meantime public confidence in the success of the undertaking must increase. At the present time the stock is one of the cheapest in the market. At present price it pays 12½ per cent. interest. It bears 10 per cent. interest and has a drawing of £3, due on the 1st of January, and the present price includes £2 10s. of accrued interest. To investors seeking large returns, this stock should be in high favor.—*Railway News.*

An Andes Railroad.—Interesting information reaches us from South America, to the effect that a scheme is on foot for the construction of a railroad across the South American continent which bids fair to rival in extent, as well as in utility, the great transcontinental routes of the United States. A prominent engineer, Mr. Rossetti, was lately appointed by the Government of the Argentine Republic to make a thorough survey of the passes of the Andes, and his report seems to bring the undertaking within practicable compass. By the pass of the Planchon, or Teno, communication may be established between existing lines on either side of the Andes by a connecting line of about 1,000 miles in length. The highest elevation reached is about 10,827 ft., and apparently there will be but one very difficult section, in the Vargara Ravine, where there is a difference of level of 1,279½ ft. in a distance of 33,800 ft., which is a grade of 70 to 1,000. Thus, the undertaking will not be on the scale of our Pacific Railroad, either for length or the number of engineering difficulties to be overcome. The entire cost is calculated at about $3,000,000 or $30,000 per mile, of which the greater portion will be in the territory of the Argentine Republic, which has prosecuted the survey—only about one-fifth of the entire expense of the work, or about $6,000 falling upon the Government of Chili. It is quite possible that this undertaking may be considered too costly to be immediately undertaken, considering the traffic which it would command; but there are many important objects of public utility that would be served. The Argentine Republic has, we believe, great expectations, both from the immigration which is likely to flow into it, and the richness of the mining districts which will be opened. Beside these, there is a considerable trade between the eastern and western coasts, and the route would almost certainly command the mail and passenger traffic of Peru and Chili with Europe and the United States. Possibly it would form another practicable route between Great Britain and her Australian colonies. The original projectors of a railway over the Andes had at least the latter among the objects to be served by the road when completed. The line, it is said, might be built in four years, but the Argentine Republic will be surer of success in the undertaking if they take plenty of time to the work and gradually extend the line westward. The projection of such a scheme at the present time indicates a growing prosperity in the South American republics interested in the undertaking. We have been accustomed to look upon them as unprogressive nations, content to submit to the worst forms of anarchy that could exist under the name of organized governments, and probably this very general impression is not wholly without foundation in fact; but if a material enterprise as vast as the construction of a trans-continental railroad is seriously contemplated, it is evident that the two Governments interested in the proposed road are not wholly without resources, and have not lost entirely the confidence of capitalists and of the public at large. Thirty million dollars is rather more money than a disorganized anarchy, subject to periodical revolutions, could raise for internal improvements.

ORDNANCE AND NAVAL NOTES

The Prussian Percussion Fuze.—The percussion fuze used by the Prussian artillery consists of a small metal socket into which fits a metal striker, which is a nearly cylindrical piece of brass, having at one end a needle point. The socket with the striker in it is carried in the shell, being fixed in its place by means of a screw plug which screws into the nose of the shell. The screw plug is tapped for the reception of a small detonator, which, however, is not screwed in until the shell is required to be used. The striker, being free to move forward by its own weight, would, of course, be liable directly the detonating plug is screwed in, to cause an explosion by falling forward upon it, either by the accidental tilting forward of the head of the shell, or from the jar given in loading, or by the sudden movement of the parts at the moment of firing. To prevent this, a stout iron pin is passed through the head of the shell and through the fuze between the striker and the detonator, preventing any contact between the two. The centrifugal force generated by the rotation of the shell throws out the pin immediately the shell has left the bore, and there is now nothing to prevent the striker from coming into contact with the detonator. But this it cannot do until something occurs to suddenly check the flight of the shell—in other words, until the projectile impacts upon the ground or against some other obstacle, such as a man's body, which will momentarily reduce its velocity. At that moment the striker falls forward on the same principle and from the same cause as a bad rider is thrown over his horse's head when the beast stops suddenly in its gallop. These fuzes have been much extolled, and some writers have not hesitated to ascribe to them a great part of the successes of the Prussian artillery. To our minds the fuze is open to many serious objections. That it is very far from uniform or satisfactory in its action, even in peace time, is sufficiently proved by some figures which are given by Capt. Nicaise, in his pamphlet on "L'Artillerie de Campagne Belge." The Belgians, who copy the Prussians

very closely in their artillery *materiel*, use the Prussian percussion fuze, and Capt. Nicaise says that out of 8,245 shells and shrapnel fired with this fuze between 1863 and 1869, there were 128 premature bursts=1.5 per cent.; 433 fuzes slow in action= 5.25 per cent.; 131 blind fuzes=1.59 per cent.; being a total of 692 failures=8.39 per cent. Exception may also be taken, we think, to the employment of a fuze which necessitates the operation of fixing a detonator and pin at the moment of firing—an operation which has to be very carefully performed for fear of accidents. If in the hurry of action the pin should be omitted, or if it should fall out of the shell, or if the man holding the shell and charged with the duty of keeping the pin in its place should happen to be shot, an accidental explosion, likely to be attended with fatal consequences to the gun detachment, must also certainly result. Other reasons might be given for not accepting the high estimate of this fuze, which, on insufficient grounds, seems to have been hastily formed. That the fuzes have done better than the exceedingly defective French time fuze does not prove much. At all events, the fuze is one which we should regret to see introduced into our service. Nevertheless, it may be fully admitted that the percussion fuze problem is very far from having yet been satisfactorily solved by our artillerists. It is one of exceeding difficulty; and it is quite certain that if we have not solved it in England, they are just as far or farther from having satisfactorily solved it in Prussia. In France it seems to have been abandoned in despair, and Belgium can think of nothing better than following the Prussians.—*Pall Mall Gazette*.

Breech-Loaders vs. Muzzle-Loaders.—The lesson afforded by recent great battles is thus set forth by a correspondent of the "London Times."

"As the question of the merits of breech and muzzle-loading field artillery, although settled very satisfactorily to its own mind at Woolwich by the great majority of English artillerists, is still open, and is warmly debated in beleaguered Paris, it is worth while to call attention to an unfinished article by an able writer, signing himself 'Littenant,' in the 'Debats' of the 4th of October. Relying on the details given in the work of Capt. Nicaise on the Belgian field artillery, which is almost identical with that of Prussia, the writer states—1st. As to rapidity of fire. To aim well it needs 11 min. to fire 35 rounds with a breech-loader, and 12 min. with a muzzle-loader. That is not much. 2d. As to precision, breech-loaders are incomparably superior. Here is the point on which in my small way I have insisted, and in spite of Woolwich do still insist, and will do so 'till better informed.' The table of averages for both systems, as given by M. Littenant, is as yet my full justification, if the battle of Sedan did not furnish one. The results of the experiments recited are as follows:—To touch infantry, the chances are for the Prussian gun of 4.90 per cent. at 500 metres, 70 per cent. at 1,000 metres, 50 at 1,500, 40 per cent. at 2,000. For the French muzzle-loader (to which we are assimilating) of 4, they are 80 per cent. at 500 metres, 40 at 1,000 meters, 23 per cent. at 1,500, 12 per cent. at 2,000! The French writer adds what was so terribly proved at Floing: 'At great distances our batteries have no chances against those of the enemy.' The superiority of trajectory almost follows. At 1,600 metres the Prussian breech-loader scores a column of infantry (or the ground) for 18 to 19 metres, while the French muzzle-loader only touches a line of 11 to 12 metres long—an advantage of from 20 to 26 ft. in favor of the breech-loader.

Effect of Projectiles.—The Prussian breech-loader of 4 shells on an average 40 *eclats*, of 6 ditto 35 *eclats*, as against the French muzzle-loader, 24 and 22 respectively. The grape practice of both is defective—a disadvantage not of such great importance in these days when infantry fire is so deadly at long distances, and cavalry charges and attacks on guns all but *hors de toi*. M. Littenant prefers the Prussian percussion fuzes to the French time fuzes. If he saw both used in action he could cite examples to justify his preference.

Range of Projectiles.—The Prussian breech-loaders of 4 and 9 give extreme ranges of 4,000 to 4,200 metres. The French muzzle-loaders of 4 and 12 give maximum ranges of 3,200 and of 3,000 metres.

Mobility.—The Prussian 4 weighs 1,550 kilogrammes; the 6 weighs 1,782 kilogrammes; the French 4 weighs 1,293 kilogrammes, the 12 weighs 1,937 kilogrammes.

Torpedoes.—In bringing before our readers, in as few words as possible, a short history of the torpedo, we shall show in what degree these weapons have as yet proved most effective, and also give a brief outline of their construction. We think it was in 1803 that a man named Fulton proposed to Bonaparte an infernal machine, which he promised should have the effect of destroying any ship afloat in a few seconds. He was allowed to make an experiment. The first was successful, but the next attempt failed, and the Emperor refused to countenance him further. The Crimean war was the next occasion in which torpedoes appear to have been used. But neither in the Baltic nor Black Sea did the allied fleets receive any serious damage from them. From this time to the late American civil war, little seems to have been done. The Confederate States had an extensive seaboard to protect, and were much crippled through want of war *materiel*. In this instance, in an incredibly short time they proved that they had created a most efficient mode of defence, and torpedoes seem here to really commence. Hitherto, little experience had been gained, but now the sinking in a few seconds of some of the enemy's heaviest ships was the best proof of success. This success was real, as not only was the attacking ship sunk, but in doing so it had the effect of itself creating an obstruction; the enemy had to be extremely cautious in all future attacks, to guard against the disastrous effects of the hidden foe.

The earliest kind of torpedo consisted of an iron or wooden receptacle for the charge, which was fired by a slow match, the torpedo being placed against the doomed ship. We next come to the *demijohn* torpedo. This consisted of a small tub or iron cask, containing the powder, which was fired by what was called a friction tube, effected by means of a connection with the shore. But as the operator always ran a great risk, it was desirable to dispense with him and to construct the torpedo so that it should explode on coming in contact with any vessel. The most successful torpedoes, and which maintain their high character, were constructed either of half-inch cast-iron or else of strong oaken casks, bound with wrought-iron hoops. The charges averaged 50 lbs. of powder, and were fired by a mixture of sulphuric acid with

potassium. These ingredients were placed in contact with the charge, but in separate glass tubes, which were broken by means of a simple but ingenious communication with the exterior of the torpedo. These torpedoes were most effective when attached to piles or frames, which themselves formed obstructions in a channel.

We now come to the method of firing the charge by percussion caps. This also proved most satisfactory, and was much used by the Confederates in the James River, Charleston Harbor, and in Mobile Bay. The chief objection to it was the liability of its becoming useless through the attachment of marine worms, etc., as was proved on more than one occasion. We next come to firing the charge by friction. This mode, for simplicity and certainty of firing, bears favorable comparison with any other known method. The composition forming the fuse-head is made of materials producing one of, if not the most sensitive compounds. The fire created by this fuse is conveyed to the powder by means of a rapidly burning composition placed between the fuse and the charge.

We would lastly refer to the torpedo fired by means of electricity, either by the incandescence of wire, or by the direct magneto-electric current. But we cannot speak so strongly in favor of this method of ignition, especially when we consider the simplicity and effectiveness of explosion caused by "percussion" or by "friction." And there is little doubt these two latter plans will for a long time prove to be the most efficient. Respecting the amount of charge used, it has been proved by actual experience that 50 lbs. of powder may produce the most disastrous effects. Few if any vessels escape foundering on the explosion of such a charge under them. It has been proved to be a great mistake to use too large a charge, for this simple reason—the receptacle which contains it is seldom made strong enough to resist the force generated by the entire ignition of the powder; so that often the explosion is premature, as proved by the unburnt powder blown into the water.

Field Artillery.—The following very sensible remarks upon the subject of field artillery are from the "Delhi Gazette:"

"We promised, in a former number, to revert to this subject, having somewhat more to say on heavy artillery and large-bore guns. But our remarks to-day must be on field artillery and light guns, having been led thereto by the recent essay on furious driving of Royal Horse Artillery guns, as published by one of the Inspectors General of Royal Artillery. We confess to having seen and felt a thrill of childish delight when a battery of Royal Horse Artillery has galloped past the flagstaff by half batteries at close intervals; eighteen horses abreast whirling three light guns passed us with the rushing noise and nearly the velocity of a rocket. We confess we should be sorry to see this dash taken out of our Royal Horse Artillery, and the arm brought down to the quiet, tame, necessary jog-trot of a field battery having heavier guns. Moreover, we see no reason for this *elan* being taken out of the Royal Horse Artillery, as we can find but three elements of danger in this pace, separate and over and above those attending all mounted men's necessarily quick paces, and we will here mention them as they appear to us remediable. 1st. Then, why should a body of men (called detachment) ride immediately in front of the guns; so that should man or horse fall, as at Morar, over him or it the guns must go? We are confident no artillery officer would place his detachment thus were it not so laid down in books of drill for purposes of show; we can call to mind one only use of this order, and that is of occasionally masking the guns and making an enemy suppose it is cavalry without guns. 2d. Why should two unfortunate men be stuck on the gun limbers? They are literally sitting on small magazines of gunpowder! We believe many more ruptures and other injuries and accidents are sustained by 'limber men' than by the single riders in the detachments of Royal Horse Artillery. No one can conceive who has not tried it, the misery of sitting on a cart without springs, and being taken *nolens volens* and at all paces, not over a smooth parade, but over hillocky ground with an occasional ditch to jump of a foot or two in breadth; any of our readers may try it by going across country in an *ekka*, and even then they will have the best of it. The use urged for this absurdity is that the limber men can dismount and get the gun more quickly into action than can the mounted men of the detachment, whereas it is very doubtful if there is more than a quarter of a minute of difference in favor of the limberman, and that can scarce compensate for the risk of life and limb; while many a Royal Horse Artillery captain must feel hampered and dare not go over bad country which he might otherwise do had he all his men mounted on horses. It may also be urged on the score of economy, that two men more are trotted into the field with three horses less. This we would, with all deference to our military friends, urge is a very questionable gain? We would ask, if the seats of our limbers are full, how can you in action carry off a disabled carriage or men? Or, again, if your team horses are knocked over and you replace them from the detachment, where do the men go? The last remark we have to make is on the adoption of what is called close 'intervals;' why three or six carriages should be driven abreast at only a yard apart, we cannot think, except it be when there is no room for the guns on any particular ground to manœuvre at greater (intervals) distances from each other, which seems to be a manœuvre fraught with unnecessary danger. We challenge discussion on these three points: 1, detachments front; 2, limbermen; 3, close intervals. We think they may all three be beneficially done away with, and we, with all due respect to opinions of the Inspector General, should be sorry to see the day when our far-famed Royal Horse Artillery do not go 'the pace,' and cannot go across any country where they are required to support our cavalry in their charges, or to lead the van of the army. The present Inspector General of Royal Artillery is too keen a Horse Artillery man to recommend any step that would take anything from the *esprit* and dash of this noble right arm of the service."

The "Glatton," 2, double-screw turret ship, armor plated, 2,709 tons, building in Chatham Dockyard, is making very satisfactory progress, more hands having been lately placed upon her, and it is expected that she will be ready to be floated out of dock this month in a very forward state. A large number of men are employed upon the turret, in which will be placed the immense guns with which the ship is to be armed. The breastwork of the turret is nearly completed, but the turret itself is only being prepared for the ar-

mor plates. The armor used for the "Glatton" will be of unprecedented thickness. The armor of the breastwork of the turret is formed of 12-in. plates, but the turret itself will be protected with armor no less than 14 in. thick, the heaviest plates ever yet manufactured for our ships of war. The breastwork of the turret, the armor, the teak backing, and the inner iron skin will be nearly 3 ft. thick. The plating of the broadside of the ship is completed. Amidships the armor is 12 in. thick, but is reduced to 10 in. fore and aft. The armor plates for this formidable ship have been supplied by the Camell Ironworks Company, at Sheffield. The hurricane deck is in course of construction, and the whole work of building the ship appears to be making rapid way.

Some time has now elapsed since the ocean-cruising turret frigate "Monarch," was inclined at Portsmouth to ascertain the exact measure of her stability, and the calculations made from the data then obtained have now been concluded and deposited with the department of the Controller of the Navy. It is reported that these calculations prove the measure of the "Monarch's" stability to be so much less than had been anticipated previous to this trial, that it is very possible a determination may be arrived at to reduce the ship's masts and spars, remove the hurricane or spar deck, and redistribute some of the weights stowed on the turret deck. After the dreadful experience in these matters gained from the foundering of the "Captain," it is fully expected that the First Lord of the Admiralty will relieve the public mind of anxiety as to the seaworthy capabilities of all the heavily armored and armed ships of her Majesty's navy, by making public the results of the calculations made from these inclining experiments.—*Mechanics' Magazine.*

A greater tonnage of iron ships is now in course of construction on the Humber than at any previous time in the history of iron shipbuilding. Messrs. C. & W. Earle have on the stocks in their yard seven large steamers—one of 2,000 tons, for a London house; four 1,800 tons each, for Messrs. Wilson, Sons & Co., Hull, the owners of the Wilson line; and two of 2,000 tons each, for Messrs. Norwood & Co. Messrs. Humphrys and Pearson have four large vessels in course of construction, and at both yards orders are in hand for other ships which will be laid down as the stocks are cleared of those now building. On Saturday, Messrs. Earle launched from their yard the largest steamer ever built at Hull. This vessel, which has been built for Messrs. J. Moss & Co., of Liverpool, was christened the "Canopus" by Mrs. Oswald Earle, of Liverpool, on behalf of Mrs. R. J. Moss, of Alexandria. The "Canopus" is intended for the trade between Liverpool and Alexandria. She is 400 ft. long, 37 ft. beam, and 27 ft. 9 in. deep. Her gross tonnage is about 3,000, and her actual horse-power from 1,500 to 1,600. The vessel left the stocks amid the cheers of thousands of spectators, who greatly admired her beautiful appearance on the water.—*Mechanics' Magazine.*

Bronze Guns.—The Belgian Government has made a series of highly important experiments with bronze guns. Two guns in the hands of the committee endured respectively 2,673 and 1,362 rounds. Several methods are employed for giving the guns greater hardness and tenacity.

ENGINEERING STRUCTURES.

Hoosac Tunnel—East End.—About 1,500 lbs. of dualin, in cartridges ready for use, reached here from Neponset ten days since, being the sixth attempt to supersede nitro-glycerine. The inventor of this compound arrived on the 28th ult., for the purpose of superintending its application in person. As this parcel had been specially prepared for the purpose, guided by the results of five previous experiments at various points of the tunnel, "great expectations" were raised as to the results. One of the slopes then being operated upon by nitro-glycerine and having a burthen of 8 ft., which was being thrown down every blast, bottoming every hole, was offered for the experiment. Similar charges of dualin were substituted for nitro-glycerine; the dualin was utterly unable to move the rock—the inventor asserting that this failure arose from the cold weather having affected the compound, the charges were thereupon warmed, but with no better result. Some charges were now inserted in holes having a burden of 2 ft., instead of 8; these removed the rock, but as powder would have done the same work, this was not deemed a success. Meanwhile some 400 lbs. of dualin were teamed to the central shaft, but as the results of three days' blasting at the east end were reported of "no account," this has not been used. We believe the results now attained with nitro-glycerine at the east end, and above described, viz., taking out the roof full width of the tunnel with a single series of seven drill holes having an 8-ft. burden, and bottoming every hole, indicates admirable direction of the work and argues well for the speedy completion of the tunnel. Progress during November, 133 ft.

WEST END.

Well No. 4, Messrs. Hocking & Holbrook have commenced using nitro-glycerine in their sub-contract, for the purpose of removing the rock preparatory to putting in the brick arch at that point; their first blast of nitro-glycerine in five holes, was tried on Monday with satisfactory results, and hereafter they intend to substitute it for powder, except in trimming. It seems to produce less jar, and it is anticipated will be less injurious to the brick work that is completed, than blasts with powder, besides expediting the work and saving money. 63 ft. of brick arch were completed during the month ending November 30.

WEST SHAFT.

The progress of the heading at this end, we understand, during the month of November, has nearly equalled that attained at the east end. When it is remembered previous to the present contract 40 ft. was more than average at this point, the progress (130 ft. during the past month) is very satisfactory.

CENTRAL SHAFT.

The advance made in the two headings just opened during the past month, was 76 ft. Considering that this rock has to be twice handled and then lifted over 1,000 ft. to the surface, such progress by hand drilling is very extraordinary work; but as Mr. Walter Shandley has been on the ground during the month, all the time, this may afford the clue how it is the headings are being driven at such a rate, by hand drilling.

Recent Visit to the Great Tunnel through the Alps.—The tunnel, as Professor Anstead has stated, will perforate the crest of the main

chains of the Alps, nearly midway between Mont Tabor and Mont Cenis, passing nearly under the summit of Mont Frejus. The operations of the tunnel involves a direct cut through a series of rocks on a line whose depth below the surface was almost at once very considerable. Owing to the form of the ground and the rise of the mountain, the depth was 2,000 ft. at each end after 2,000 ft. of tunnelling. From this point, however, the depth increased very little from each end for a long distance. In the middle of the tunnel the depth below the surface is 5,400 ft., while the deepest borings for such works as mines and wells do not exceed 3,000 ft. The works have been carried on throughout with some regard to the great physical questions involved. Among these the temperature at various distances and depths beneath the surface was not the least important. Instructions were given to bore a large hole laterally into the rock for a distance of about 10 ft., at intervals of 500 metres, and determine the temperature of the rock by thermometers provided for the purpose. On the northern side this important experiment had been carelessly executed, but on the south side, especially towards the centre, some good observations had been made, and the result was somewhat startling. The last observation made at the time of his visit was at 6,200 metres (20,342 ft.) from the south end, at a depth of more than 5,000 ft. The result was 28 deg. C.= 80⅘ deg. F. This would reduce the increment to a degree Fahrenheit in more than 100 ft., the general increase being observed in mines to average a degree in about 60 ft. Here again, however, there was still something wanting, the mean annual temperature of the surface not being accurately known, and the depth from the surface of the stratum of permanent temperature never having been determined. With reference to the progress of the work of tunnelling, the Professor stated that on the 31st of last month there remained less than 2,000 ft. out of 40,000 ft. to pierce, and as the present rate of progress is about 500 ft. per month, it may be expected that the communication will be complete by the commencement of the ensuing year.—*The Artizan.*

NEW BOOKS.

THE ELEMENTS OF PRACTICAL PERSPECTIVE. By ELLIS A. DAVIDSON. London, 1870: Cassell, Petter & Galpin. For sale by Van Nostrand.

Mr. Davidson's name is so well known in connection with Messrs. Cassell & Co.'s useful technical manuals, that no further proof is needed of the character of this volume than the author's name upon the title-page. It forms a natural sequel to "Linear Drawing," the study of which is essential to gain a knowledge of the construction of geometrical figures before the student commences the more involved problems of perspective. For the same reason the treatises on projection also take a prior place in order that the pupil's mind may become familiarized with the true forms of objects as conveyed by the parallel lines of isometric projection, before he attempts to lay them out in true perspective.

By very easy steps Mr. Davidson takes his student from the definition of the visual angle to the projection of figures at first elementary, afterwards more difficult, then through simple combinations of different forms representing familiar objects, until he takes leave of them with a brief chapter on the projection of curves. The experience of many years' teaching of pupils has given Mr. Davidson special opportunities of learning how to convey the information he desires to impart in the simplest and most effective manner, and we believe that no student will read his book in vain. We can cordially recommend it as being thorough so far as it goes, and we would recommend its being followed by another treatise investigating the subject still further. Such a book would be well received by pupils. It is of course too much to expect that within the limits of a small and cheap book, such as this manual is, any examples of drawing are given which the student can follow; the diagrams are merely exercises for him to work out, it being assumed that he has already learned the use of the drawing pen and compasses.—*Engineering.*

DRAWING FOR CARPENTERS AND JOINERS. Containing a Description of the Construction of the Subject of each Study and the Method of Drawing it; with Elementary Lessons in Freehand and Object Drawing. With 250 illustrations and drawing copies. By ELLIS A. DAVIDSON. London and New York: Cassell, Petter & Galpin. For sale by Van Nostrand.

We have here another of the excellent series of small technical manuals which has been in course of publication by Messrs. Cassell for some time past—a series which is calculated to do good service to the classes for whose use it has been specially produced. The particular volume of this series now before us is intended as a sequel to the manual on "Building Construction," by the same author, which we had occasion to notice favorably a few months ago. The book commences with an elementary chapter on linear drawing by means of instruments, and then goes on to treat of freehand drawing, drawing from solid objects, wooden bridges, linear drawing for carpenters, the development of roofs, drawing for joiners, mouldings, staircases, and freehand drawing for joiners. In dealing with these various subjects, Mr. Davidson not only shows how the different examples are to be drawn, but he in most cases explains why the particular form or method of construction represented is adopted, and his book is thus something far more useful than a mere drawing-book would be. The work is one we can heartily recommend to the classes for whom it has been written.—*Engineering.*

THE PRINCIPLES OF MECHANISM AND MACHINERY OF TRANSMISSION. Comprising the Principles of Mechanism, Wheels and Pulleys, Strength and Proportions of Shafts, Couplings for Shafts, and Engaging and Disengaging Gear. By WILLIAM FAIRBAIRN, Esq., C. E., LL. D., F. R. S., F. G. S., Corresponding Member of the National Institute of France and of the Royal Academy of Turin; Chevalier of the Legion of Honor, etc. Philadelphia: Henry Carey Baird. For sale by Van Nostrand.

From the imposing array of scientific honors appended to the author's name, our readers might be led to suppose that this work was written for others than practical mechanics, but no greater mistake could be made than such a supposition. Mr. Fairbairn, though eminently scientific, is one of the most practical of men, and he knows to a nicety the wants of practical men. This book is

written in the plainest and most concise style, and may be read with profit by those to whom algebra and geometry are unsealed mysteries. There are a few algebraic formulæ in the book, but the larger portion is written in plain English. The work treats of a great variety of subjects included in the general classification given in the title and ought to be in every mechanic's library.

ETUDE SUR LA TOUR A GAZ ET A CHALEUR REGENEREE DE M. SIEMENS. Par M. F. KRAUS, Ingenieur des Mines, Professeur de Metallurge a l'Universite de Louvain. 5 planches. Louvain, 1869. For sale by VanNostrand.

AN INTRODUCTION TO NATURAL PHILOSOPHY. Designed as a Text-Book for the Use of Students in College. By DENISON OLMSTEAD, LL. D. Second revised edition, by E. S. SNELL, LL. D. New York: Collins & Brother. For sale by Van Nostrand.

The new edition of this book will be welcomed by instructors who are familiar with the many excellencies of the older editions. As a text-book for beginners in Mechanics, it has held the foremost place in American colleges and academies for many years. The expositions afforded in the first chapters in the book of the laws of motion, the laws of falling bodies, the parallelogram of motions and forces, and the centre of gravity, are rarely if ever equalled in the text-books.

The work contains as full a course of Physics as should be required in any but the technical schools; and for students preparing for the scientific schools, whether by aid of instructors or without it, there is no better initiatory training for the extended courses of Weisbach or Rankine, than is afforded by Olmstead's Philosophy.

Prof. Snell's revisions have increased the value of the work. A chapter on Heat is added and the subjects of electricity, magnetism, and electro-magnetism are re-written. These several subjects, as presented, are fully up to our present knowledge of the topics; the number of illustrations is largely increased, and the typography is all that could be desired in a text-book.

AN ELEMENTARY COURSE OF HYDROSTATICS AND SOUND. By RICHARD WORMELL, M. A., B. Sc. Fcap, 8vo, pp. viii. and 146. London, Groombridge & Sons, 1870. For sale by Van Nostrand.

This little book is "designed for the use of schools, colleges, and candidates for University and other examinations." In such a work it would of course be out of the question to look for novelty of matter; by the nature of the case, to praise the author's originality would be to cast a doubt on his accuracy, and, while inaccuracy would be inexcusable, no merit can be claimed for its opposite. Hence, in trying to form an estimate of a book like this, we are inevitably led to consider whether the subjects treated are arranged in a simple and natural order; whether the exposition of principles is clear and logical, the really fundamental matters being kept constantly and prominently before the student's mind, and special consequences and applications grouped about them in such a manner as to show distinctly their mutual connection and dependence; whether, in short, the book is scientific in treatment as well as in subject. We are sorry to say that, in these respects, our judgment of the work before us is by no means favorable. We should expect a student, instead of acquiring from it ideas which are capable of growth and expansion within his own mind, and being led towards the conception of the organic connection of all scientific truth, to conclude that science—or at least hydrostatics and acoustics—consists of a series of propositions which it is his duty to "get up" and write out on the first opportunity in answer to examination-questions. The least satisfactory parts of the book are the explanatory and descriptive portions, and especially the 22 pages at the end, devoted to sound. The author says in the preface that "the whole contains all that is required on these subjects [hydrostatics and sound] for the B.A. and B.Sc. degrees of the University of London." If this is true as regards the latter subject, it is more to the discredit of the University than to the credit of his book.—*Nature.*

MISCELLANEOUS.

WILL our excellent trans-oceanic contemporaries, the "Building News" and the "English Mechanic," please give us credit when they borrow our translations or contributed articles?

THE GREAT AMERICAN LAKES.—The following statement regarding the dimensions and altitude of the great American Lakes will serve to correct the errors of a paragraph in our last volume:

	Area sq. miles.	Elevation.
Lake Superior	32,000	600 ft.
" Huron	20,000	579 "
" Michigan	22,000	579 "
" Erie	9,600	565 "
" Ontario	6,300	232 "

The area drained by these lakes according to Professor Silliman is 335,515 sq. miles, and the average quantity of water passing over Niagara Falls is 22,440,000 cubic feet per minute.

A SURVEYOR IN 1678.—The following is an exact copy of an advertisement which appears in a publication dated 1678:—

"James Ward, of Langley, near Windsor, Surveyor, can perform Artificially the Conveying of Water, either by Channels or Cutting New Rivers (in any places where 'tis possible to be done): He can also build new, or repair old Bridges over Rivers, and undertakes the new building or reparation of Water-mills, or any water-works; the hanging of Bells, Dyalling. Surveying of Lands, Gaging of Vessels, &c. He has lately invented an Engine for the pumping of Water, which by the assistance of one man (only) will pump two Tun of Water in one Minute (as has been experimented in St. James's Park) and is of excellent use in the Floating or Draining of Grounds, Fen-Lands, Tin-Mines, Ships, also for Brewers use, &c. This Engine will raise water 100 foot high and upwards. He hath exceeded all that hath been done of this kind.—*Building News.*

INFLUENCE OF CANNON-FIRING UPON RAIN.—M. Charles La Maout, apothecary at Saint Brieuc, in France, has published some interesting observations on the influence of artillery-firing upon the fall of rain and the force of the wind. During the siege of Sebastopol, soon after the firing commenced the sky became obscured with clouds and

a fine rain began to fall, which was sometimes followed by a deluge or whirlwind. Immediately, and as a consequence of the condensation, the mercury in the barometer rose in proportion to the violence of the cannonading. A chart of the movements of the barometer afforded a good indication of the bombardment. The author then proceeds to show how rain could be produced at will by a judicious discharge of artillery. There is no doubt that this would be a better use of cannon than the wholesale slaughtering of men, but whether rain could be produced at will in this way is another question. There is some confirmation of the theory in the fact that a violent rain fall has attended the recent engagement of troops near Metz, in France. The subject is one quite worthy of investigation, and if it were found to be expedient the proposition of the author to establish meteorological stations with suitable artillery ought to be carried into execution.

THE COST OF WAR.—In a Parliamentary paper printed by order of Parliament in 1828, which contained the result of the labors of the Select Committee on Public Income and Expenditure, some tabular statements are given showing the difference between the public receipts and expenditure during various periods, and among others for the ten years of war which ended with the peace of Amiens in 1802, and for the fourteen war years which terminated with the peace in 1816. The following is an abstract of this statement from the first of these periods :—

Total expenditure		£447,812,900
Total income from taxes		258,659,000
Excess of expenditure over revenue		£189,153,000
Total sum raised by new loans, etc.		£380,997,000
Of this sum there were applied to—		
Redemption of old debt	£180,346,000	
Lent to Austria	4,600,000	
Discount and other charges of receipts	2,416,000	
		£187,362,000
		£193,634,000

Leaving a balance to the Exchequer on January 5, 1802, of a trifle over 9,000,000.

The abstract for the 14 years ending January 5, 1816, is still more remarkable—

Total expenditure		£1,059,683,000
Total income from taxes		823,354,000
Excess of expenditure over income		£236,329,000
To meet this deficiency and to pay off portions of the existing debt, there was raised by new loans		£900,107,000
Of the sum so raised there was applied—		
To pay old debt	£651,952,000	
Lent to the East India Company	2,500,000	
Discount, etc	28,877,000	657,339.000
Total sum applicable to meet deficiency of income		£242,767,000
Leaving a balance in hand on January 5, 1816, of a sum of		£15,500,000

The total excess of expenditure over the ordinary income of the country during the 24 years of war, from 1692 to 1816, amounted to the enormous sum of £225,482,000.

REMARKABLE ENGINEERING OPERATION.—The recent change of grade in Fifth avenue, between Sixty-eighth and Seventy-second streets, laid bare the two large 3-ft. iron water pipes which supply the city below Central Park, and rendered it necessary for them to be lowered to the depth of about 4 ft., in order to protect them from frost and from injury by the constant passing of vehicles. As one pipe is not of sufficient capacity to supply the wants of the city below Central Park, it was decided to prepare a bed on the west side of the avenue as a temporary resting place for the pipes, while a proper trench, 12 ft. wide and from 1 to 4 ft. deep, could be excavated for them beneath the line they had occupied. This was no easy task, as the pipes were then laid in a trench cut through solid rock, and, before they could be moved an inch, one side of the trench had to be blasted and removed with the utmost precaution. When the temporary bed, some 8 to 10 ft. wide, was properly prepared, the Croton mains, each about 1,000 ft. in length, were slipped sidewise on wooden blocks with great care, so as not to disturb any of the joints.

The magnitude of this task may be inferred from the fact that every foot of the pipe, including the water contained therein, weighs about 1,500 lbs.

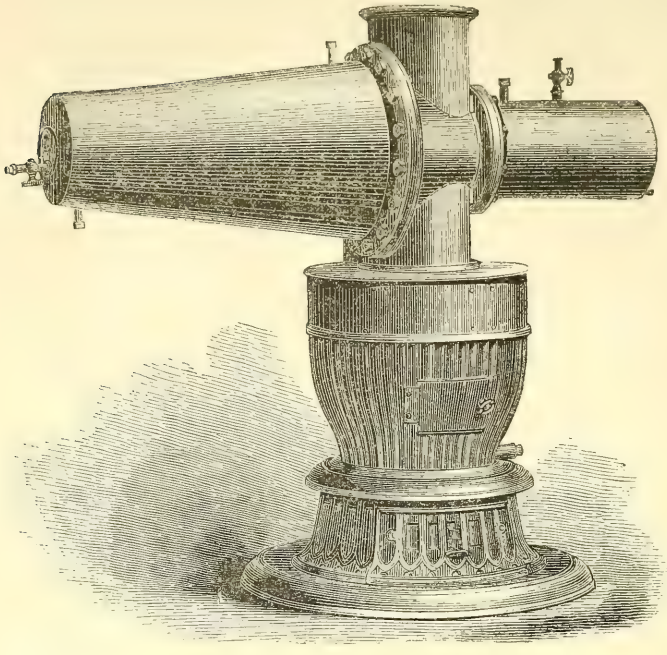
After the pipes were shifted to the temporary bed, a trench 12 ft. wide and from 1 to 4 ft. deep, was excavated through the solid rock along the centre of the avenue. Into this the pipes are now lowering without interrupting the flow of water through them. The pipes were laid in 1840, and appear to be very little corroded, and the hemlock blocks from the northern part of the State, upon which the pipes have rested for the last 30 years, are as sound to-day as they were when buried with the pipes.

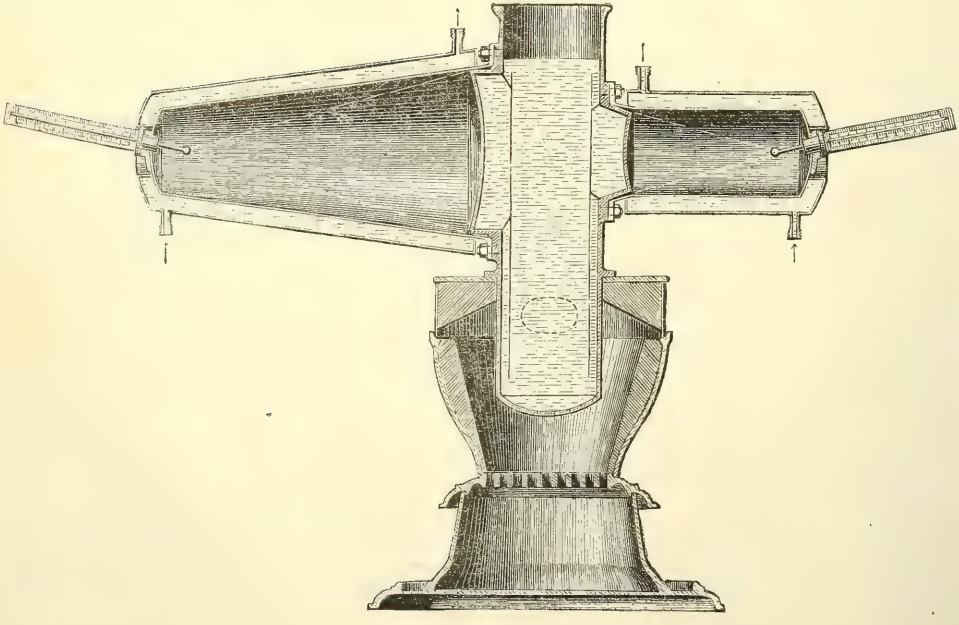
NEW SOURCE OF MINERAL WEALTH IN NEVADA.—The Commissioner of the General Land Office is in receipt of samples of potash salts from the newly discovered and extensive deposit in Churchil county, Nevada. As a new source of mineral wealth connected with the development of chemical industry the subject is of public interest. Not only do the salts furnish the purest potash, but the lye therefrom is available for bromine, the price for which since 1865 has fallen to one-fourth of its former cost. Hitherto the sources of bromine have been the mother of lyes, resulting from the evaporation of sea water in Southern France ; the kelp or varec (a species of algæ) of Nether Bretagne and England, and the water of the Dead Sea. The latter contains already, at a small depth, 0.7 per cent. of bromine, which is separated by means of bichromate of potash and muriatic acid.

Since the discovery of the potash deposits in Strassfurt, all these sources have been unavailable. The lyes of chloride of magnesium, a product in the manufacture of the potash salts, contain from 0.15 to 0.25 per cent. of bromine, which is extracted by subjecting them to distillation with peroxide of manganese and muriatic acid, and refining the obtained bromine in the ordinary manner. The Strassfurt bromine is nearly chemically pure ; it supersedes the English and French, and has pushed them already from the market. In the manufacture of aniline colors it has become the substitute for iodine, and is already in extensive use as a disinfectant in the European hospitals, owing to the fact that it affects the lungs less than chlorine.

CAPTAIN ERICSSON'S SOLAR PYROMETER.

PAGE 113.





VAN NOSTRAND'S
ECLECTIC
ENGINEERING MAGAZINE.

No. XXVI.—FEBRUARY, 1871.—Vol. IV.

SOLAR HEAT—THE TEMPERATURE OF THE SUN.

By Captain JOHN ERICSSON.

[From "Engineering."]

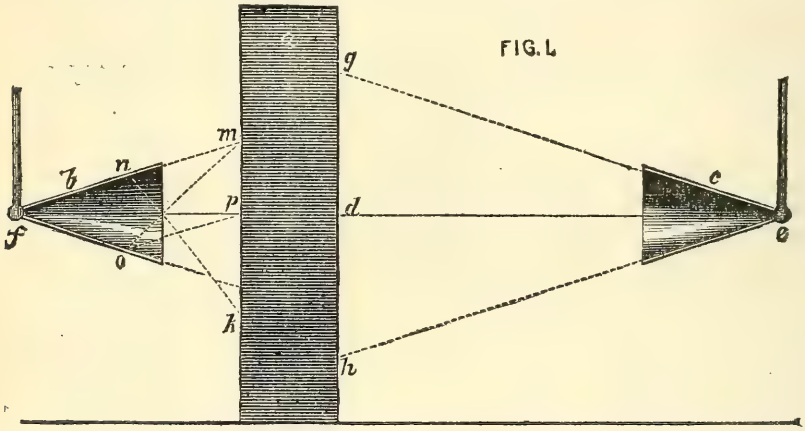
Probably no subject connected with physics, supposed to be known, is so imperfectly understood as the propagation of radiant heat. The recognized law that the temperature imparted to substances exposed to radiant heat, diminishes in the inverse ratio of the square of the distance from the radiating body, is true only of a sphere of perfectly uniform temperature at the surface, if the distance be reckoned from the *centre* of the sphere. The temperature produced by radiation of spheres which are not uniformly heated at all points of their surface, and of other bodies of whatever form, even though they be uniformly heated through the entire mass, we have no means of ascertaining at a distance, however accurately that distance may be known. Nor will it avail if, in addition to the assumed uniform temperature and accurate knowledge of distance, we also know the dimensions and weight of the radiating body. In fine, notwithstanding our knowledge of these elements, an attempt to solve the problem will be fruitless, unless, as before stated, the radiation proceeds from a *sphere* of known dimensions having a perfectly uniform temperature at its surface. Agreeable to the theory of Melloni, however, which theory a high authority assures us has been unanswerably demonstrated by the celebrated Italian, the matter is very simple, viz., the temperature at intermediate points between a heated body and thermometers exposed to and indicating the intensity of the radiant heat, may be determined by squaring the respective distances. The products, it is asserted, will show exactly the inverse ratio of the intensities and consequently the temperature at intermediate points, due to their distance from the radiating surface.

It will be necessary, before entering on a demonstration intended to show the temperature of the sun, to define clearly the law which governs the propagation of radiant heat. I propose, therefore, to examine carefully the merits of Melloni's mode of establishing the infallibility of the propounded theory, that the temperatures imparted to bodies exposed to radiant heat are in the inverse ratio of the distances between the radiating surface and those bodies. Fig. 1 is a diagram showing the leading features of the method adopted by Melloni. *a* represents the side of a square vessel filled with hot water, the faces of which, right and left, are coated with lampblack and in all respects alike. Hollow cones *b c* exactly similar, lined with black paper on the inside and provided with thermometers inserted near the apex, are applied at different distances in opposite directions, their axes being in a line and at right angles with

the faces of the heated square vessel. Melloni states that the temperature indicated by the distant thermometer, *e*, will be precisely the same as that indicated by *f*, however near the latter may be to the vessel, provided the elongation of the sides of the distant cone, *c*, shown by the lines *e g* and *e h*, do not extend beyond the limits of the radiating surface. An inspection of the diagram will convince the attentive observer that because the points, *g* and *d*, of the radiating surface are not equidistant from *e*, the radiant heat which they emit, cannot affect the thermometer, *e*, alike. The extent of the irregularity may be readily determined by squaring the distances *g e* and *d e*, in conformity with Melloni's theory. Now the proportion of these distances as shown by the diagram, is 20 to 19, hence the radiant heat transmittted to the thermometer from the points *g* and *d* will vary in the inverse ratio of the products of the stated numbers, viz., as 361 to 400. This great difference of intensity of heat transmitted to the bulb of the thermometer from different points of the face of the radiating vessel, will evidently occasion conflicting molecular motion within the contents of the bulb, fatal to precise indication.

The readers of "Heat as a Mode of Motion" may with propriety ask, if the intensity indicated by the thermo-electric pile during the reported experiments was that due to the radiant heat transmitted from *g* in the line of *g e*, or that trans-

FIG. 1.



mitted from *d* along *d e*? It could not possibly be both, as we have demonstrated that these intensities, when reaching the bulb of the thermometer, vary in the proportion of 361 to 400. It will be seen, therefore, that Melloni's demonstration is quite unsatisfactory. Several minor imperfections inseparable from the method adopted by the Italian physicist might be pointed out, all tending to augment the errors adverted to. The black paper which lines the inside of the hollow cone *b*, as it is very light and incapable of reflecting the radiant heat transmitted by the rays indicated by *k n* and *m o*, will at once become heated. Consequently the air contained within the cone will speedily have its temperature raised by convection, reflecting its heat against the thermometer at *f*, and thereby contributing to disturb the indication already fatally affected by the difference of temperature consequent on the varying intensities of the radiant heat before alluded to. The relative intensities imparted to the black paper within the cone at *o*, and that transmitted to the bulb of the thermometer at *f*, will be determined by squaring the length of the heat rays *p o* and *p f*. The diagram shows that these lengths are as 3 to 5; hence by squaring and inversion we find that the temperature imparted by the radiant heat at *o* will be greater than that at *f* in the proportion of 25 to 9. Black paper being a powerful radiator, while air has very small specific heat, it will be seen that the volume within the cone will be rapidly heated by convection, and hence the thermometer at *f* elevated to a degree far beyond that which it would reach by the direct radiation of the vessel *a*. It will be evident that when a thermo-electric pile is em-

ployed in place of a thermometer, the disturbing influence of the heat imparted to the volume of air in the cone will be instantaneous. But let us dismiss the consideration of defects of arrangement, and proceed to test the truth of the general theory supposed to have been established by Melloni, namely, that the temperatures imparted to bodies exposed to radiant heat are inversely as the squares of the distances between the radiating surfaces and those bodies. For this purpose let us employ in place of the square vessel containing hot water a block of iron of similar form, heated to such a degree that a thermometer placed at a distance of 30 in. from its face will acquire 40 deg. above the temperature of the surrounding air. (Actual trial has shown that such a block, 36 in. square, heated to 600 deg., is capable of elevating the temperature 40 deg. under the stated conditions.) Having previously ascertained that the thermometer marks exactly 40 deg., let it be moved towards the radiating surface to a point 10 in. distant from the same. What increase of temperature will attend this advance of the thermometer towards the radiating surface? According to the theory the truth of which we are going to test, the increase will be inversely as the square of 30 is to the square of 10, namely, 100 : 900=1 : 9. Accordingly, the elevation of temperature will be $9 \times 40° = 360°$. In like manner the theory shows that if we place the thermometer 5 in. from the radiating face the temperature will increase in the ratio of 25 : 900=1 : 36 ; hence the thermometer will indicate $36 \times 40° = 1440°$. A further move of 2 in. will place the thermometer 3 in. from the radiating surface, at which distance it will be subjected to an increase of temperature in the inverse ratio of the square of 30 to the square of 3, namely, 9 : 900=1 : 100 ; the thermometer, therefore, will indicate $100 \times 40° = 4000$. But the temperature of the radiating block of iron is only 600°. The fallacy of the theory under consideration proved by this demonstration is so self-evident that it would be waste of space to prosecute the investigation any further. Melloni's device is, however, important, as it corroborates the established fact that an increase of the surface of the radiator is capable of elevating the temperature of a substance exposed to the radiant heat without increasing the temperature of the radiator ; and that the degree of elevation will be in exact proportion to the increased area. The importance of this fact cannot well be overstated. It flatly contradicts certain modern speculations regarding radiant heat, and it affords a landmark which, though it does not point out what we seek, guards against taking the wrong course.

The defects of Meloni's method, and its utter inadequacy to solve the problem under consideration, suggest the question: Is it possible to determine, by calculation, what temperature substances will acquire by being placed at different known distances from the surface of a heated body of known temperature and dimensions, the sides of which are straight and parallel? We are compelled to admit that the question thus presented cannot be satisfactorily answered, because each point of the radiating surface, in consequence of varying distance, transmits a different degree of intensity to the exposed substances. The difficulty of solution is increased on account of the stipulated form; the inferior intensity transmitted from the corners of the radiator rendering the question exceedingly complicated. A radiating plane surface of *circular* form somewhat simplifies the question; yet the difficulty remains of dealing with the inferior power of the heat rays emanating from the circumference, which, when reaching the bulb of the thermometer, occasions the conflicting molecular motion before pointed out. To overcome this difficulty, I have constructed an instrument—shown by the illustrations, Fig. 2 representing a longitudinal section, and Fig. 3 a perspective view (copied from a photograph), in which the radiating surface is concave, forming part of a sphere whose centre is situated near the centre of the bulb of the thermometer employed to ascertain the intensity of the radiant heat. But this expedient of employing a concave spherical surface, every point of which is equidistant from the bulb of the thermometer, prevents any change of distance between the same and the radiator during experiments. I have accordingly introduced 4 distinct discs of varying spherical concavity, with a thermometer placed in the centre of curvature of each. These 4 concave discs form the sides of an open

FIG. 2.

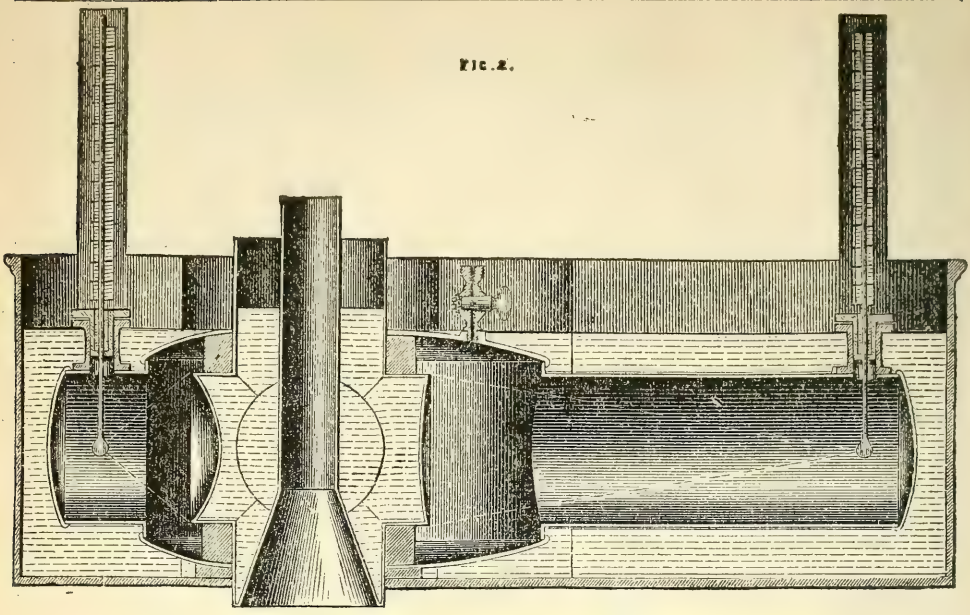
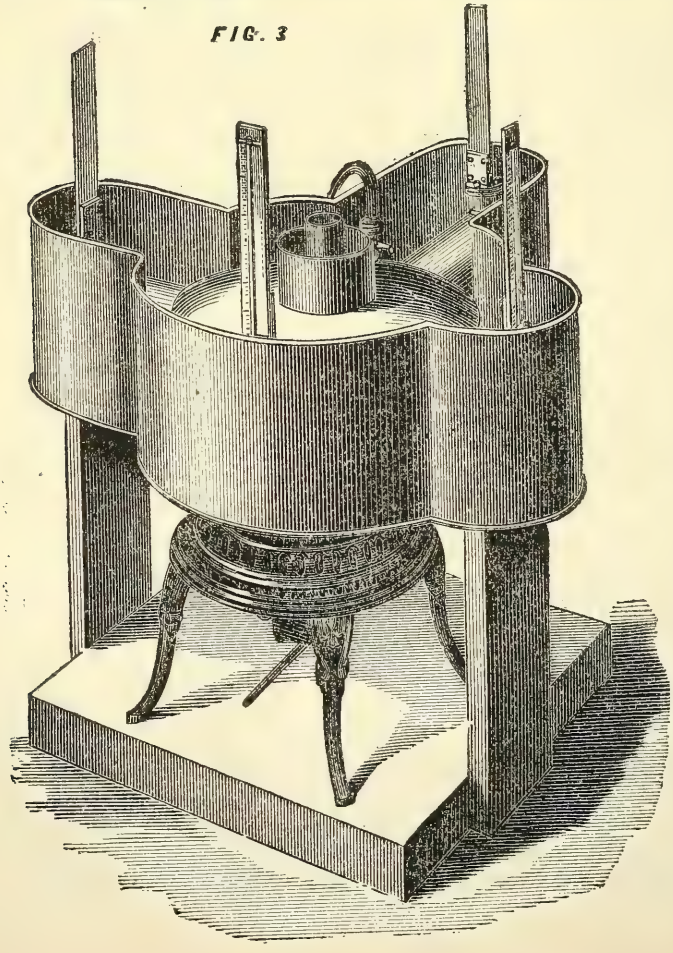


FIG. 3



vessel filled with oil, heated by a gas flame. In order to facilitate comparison, a regular gradation of curvature has been adopted; the radius of the deepest concavity being 3 in., the next being 6 in., then 9 in., and, lastly, 12 in. for the least concavity. It will be evident that, owing to the difference of concavity, each disc will present a different extent of radiating surface, if an uniform size be employed, thereby rendering comparisons between the indicated intensities quite laborious. To obviate this, the diameters of the several discs have been so proportioned that the superficial measurement of each is precisely alike. The disc of the least curvature is 4 in. in diameter; the remaining 3 being respectively 3.982 in., 3.939 in., and 3.777 in. diameter. Much pains have been bestowed on the workmanship in order to obtain concavities of precisely equal areas. The objections urged in connection with the solar calorimeter and actinometer against conducting thermometric observations in the presence of the disturbing influence of the surrounding air, apply with equal force to the apparatus now being considered. Accordingly, the heater, with its 4 concave radiating discs and thermometers, are enclosed in an exhausted chamber, as will be seen by reference to Fig. 2. Evidently, the heat reflected by the sides of this chamber towards the bulbs of the enclosed thermometers, will determine their zero precisely as in the actinometer; hence, it is indispensable that this chamber should be maintained at a constant temperature. This is effected by surrounding the same with an external open vessel filled with water kept at a temperature of 60 deg. Fahr., during experiments. The object of adopting 60 deg. is that of facilitating comparisons with solar intensity, the zero of my actinometer, as stated in a previous article, being also 60 deg. above Fahrenheit's zero. It will be proper to consider briefly the leading properties of the illustrated device. In the first place, the radiating concave surfaces, as well as the bulbs of the thermometers, are surrounded by the ether alone, and therefore cannot suffer any loss of heat by convection. Secondly, the intensity of the radiant heat received from all points of each concave surface will be precisely alike, because those points are equidistant from their respective thermometers. Thirdly, the concave surfaces presenting equal areas, being composed of the same materials of uniform thickness, and being heated by the same medium, will emit an equal amount of heat. Fourthly, as the several thermometers are exposed to the radiation of a surrounding vessel kept at 60 deg., they will acquire that temperature before fire is applied to the heater. In consequence of this, the increase of temperature, after heating, will furnish a true comparative measure of the force of the radiant heat transmitted from the concave radiators to the bulbs of the thermometers.

The prevailing notion that there is a concentration of heat in the focus of spherical radiators, will be urged as an objection against the described method of measuring radiant heat. A careful examination of this question will be necessary, as it is intimately connected with solar radiation and solar temperature. Fig. 4 represents a concave spherical radiator, *c* being the focus, *o c* the axis, and *a b* section of the radiator. Agreeable to the accepted theory of radiation, rays of heat are projected in all directions from every point of the radiating surface. In order, therefore, to demonstrate that there is no concentration of heat in the focus, we have merely to draw radial lines representing the heat rays, from points *d* and *f* on the concave surface, as shown on the diagram. It will be seen on close examination that there is only a single ray, *d c*, emitted from the point *d*, which is directed towards the focus *c*; the ray *f c* being the only one directed from the point *f*. The other heat rays from the points *d* and *f*, diverge in all directions, and intersect every part of the field *k l*; thus dispersing the radiant heat nearly uniformly over a very large surface. The curve *c n*, struck from the point *f*, clearly shows that all the heat rays below *c*, projected from *f*, are shorter than those directed to the *focus* from the same point, and therefore impart a higher temperature to the plane, *k l*, than that transmitted to the focus. It will be needless to enter on a detailed computation of the temperature at the intersections of the various rays with the plane, *k l*, as a mere inspection of the diagram distinctly shows that the focus, *c*, receives no increase of heat on account of being the centre of the spherical radiator. Indeed,

if we substitute a *plane* circular disc extending from *a* to *b*, a greater amount of heat will be transmitted to a thermometer placed at *c*, than with the spherical surface represented; the only important difference being that a thermometer placed in the focus of the latter receives an equal degree of heat from each point of the concave surface.

FIG. 4.

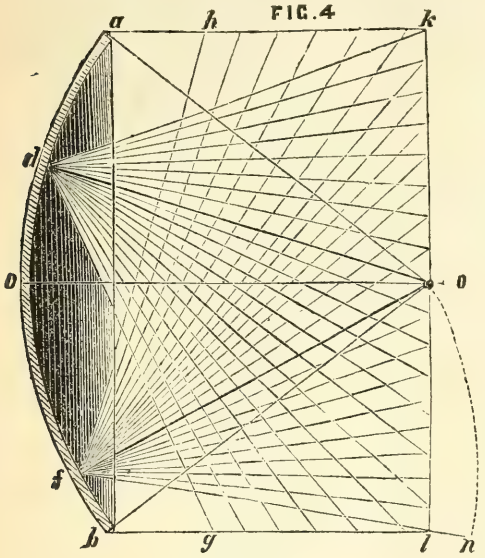
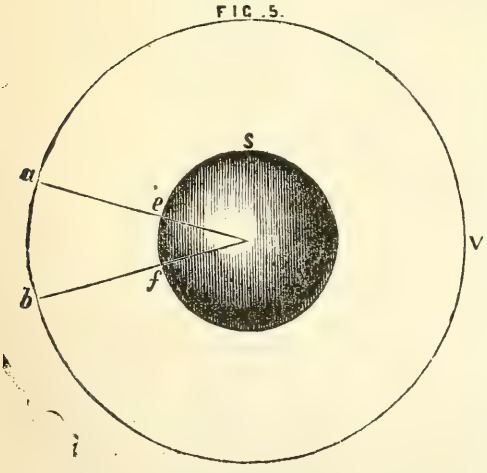


FIG. 5.



Investigations conducted by means of the illustrated instrument prove that the intensity of heat transmitted by the radiation of concave spherical surfaces of equal temperature, presenting equal areas and having different curvature, is in the inverse ratio of the square of their radii, provided the substance which receives the radiant heat is placed in the focus of the radiating surface. This important fact in connection with the previous demonstrations showing the fallacy of the propounded theory that the intensity of radiation diminishes in the inverse ratio of the square of the distance, between radiators and the recipients of their radiant heat, enables us now to consider the proposition contained in our introductory remarks, viz., that the assumed law is true only of a sphere of perfectly uniform temperature at the surface, if the distance to the recipient of the radiating heat be reckoned from the *centre* of the heated sphere. Suppose that *s*, Fig. 5, represents a solid sphere of metal maintained at a constant temperature and suspended in the centre of an exhausted metallic spherical vessel, *v*, the size of which is much greater than that of the solid sphere; *c a* and *c b* being radial lines drawn from the mutual centre, *c*, to the circumference of the exhausted vessel. The heated sphere being maintained at an uniform temperature while the spherical vessel is exhausted, and thereby freed from any disturbing influence of currents of air, it will be evident that the intensity of radiant heat, thus transmitted from the sphere through the ether alone, will be alike at every point of the surface of the surrounding spherical vessel. Obviously, the temperature resulting from radiation against the latter will be less than that of the central sphere in proportion to the area presented by each. In other words, *the temperature will be inversely as the areas of the two spheres.* On the soundness of this proposition depends the correctness of the accepted doctrine relating to the propagation of heat and light through space. The remarkable fact must not be overlooked, that this proposition takes no cognizance of *distance;* and that it enables us to determine the temperature of the central sphere merely by comparing the relative *areas* and ascertaining the degree of heat which is transmitted from the central to the surrounding sphere; the intervening space, whether it be 1 mile, or 1,000 miles, being an element excluded from our calculation.

That rays of light and heat meet with no appreciable resistance in their passage through the ether is an irresistible inference to be drawn from the fact that the

intensity depends solely on the *area over which the rays are dispersed.* The common expression that "the intensity of light and heat varies inversely as the square of the distances" leads to the supposition that *distance* is an element to be taken into account in estimating the intensity of radiant heat. That this is an error will be readily perceived if we reflect on the fact, just referred to, that the intensity of the rays diminishes in the *exact* proportion to the areas over which they are dispersed. It is self-evident that if distance, *per se*, in any way affected the question, the intensities could not thus depend solely on the extent of the *areas* over which the rays are diffused. I will endeavor to show, at the proper time, that the force of solar radiation would be in the ratio of the square root of the cubes of the distances, if dispersion did not alone determine the question. Much misapprehension would be prevented if the law relating to radiant heat were thus expressed: *The intensities are inversely as the areas over which the rays are dispersed.* Sir Isaac Newton, referring to the intensity of the sun's radiant heat at different distances, thus clearly defines the question: "The heat of the sun (at various distances) is as the density of its rays." He also states that the densities of the diverging rays are "reciprocally as the square of the distance from the centre of the sun," a fact which evidently has nothing to do with the main proposition, as it simply results from certain geometrical relations, viz., that the areas of transverse sections of a cone are as the square of the distances from the apex.

I will now proceed to show why the theory of Newton, supposed to have been proved by Melloni, is true, under certain conditions, as regards an uniformly heated sphere, although fallacious, under all circumstances, as regards plane surfaces. Referring again to Fig. 5, let us assume that the sphere S represents the sun, the semi-diameter of which is 426,292 miles; and that *a b v* represents the earth's orbit reduced to a circle whose radius corresponds with the earth's mean distance from the sun's centre, 91,430,000 miles. Now the arc *e f* is to the arc *a b* as the radial line *c e*, representing the sun's radius, is to *c a*, representing the earth's distance from the sun's centre. Agreeable to the stated dimensions, therefore, *c e* is to *c a* as 1 to 214.44; hence, regarding *a c b* as a cone, the area of *e f* is to that of *a b* as 1 to the square of 214.44=45,984. Accordingly, the temperature of the heated central sphere S will be 45.984 times greater than the temperature which it imparts by radiation to the surrounding sphere *a b v.*

We have now fully established the fact that although the extent of the radiating and recipient surfaces, in connection with the temperature of the former, determines the temperature transmitted to the latter, wholly independent of distance, yet, as regards the sun, the temperature produced by the radiant heat of his rays, is inversely as the square of the distance reckoned from his *centre*, the same law applying to all spheres having an uniform temperature at the surface.

The law which governs the propagation of radiant heat being thus established beyond contradiction, we may at once enter upon the consideration of the sun's temperature. Evidently this problem cannot be solved unless we know the diameter of the sun, the distance between the surface of the earth and the centre of the sun, and also the intensity of the sun's radiant heat at the point where the rays enter our atmosphere. By means of thermometers we can ascertain the temperature of substances exposed to solar radiation, and by deducting from the same the temperature of the surrounding atmosphere, we can determine the intensity of solar heat near the surface of the earth. Adding to this the loss which the radiant heat sustains during the passage of the rays through the atmosphere, we are enabled to estimate the intensity of solar radiation at the boundary of the earth's atmosphere, provided the thermometric observations are correct. The employment of the actinometer in place of the ordinary thermometers, relieves us from all uncertainty in regard to thermometric determinations. In the first place, its indication is not affected by changes of terrestrial temperature of any kind, hence it may be employed at all seasons. Secondly, it assigns to solar intensity a fixed position on the scale, the thermometric interval which marks that intensity being affected alone by *change of distance between the sun and the earth.* Of course, in all computations based on observation, due allowance must be made for the sun's zenith distance.

The eccentricity of the earth's orbit being 0.01679, the distance from the sun during the summer solstice will be 0.03358 greater than at midwinter. This difference, fully 3,070,000 miles, is so considerable that actinometer observations carefully made at the two extreme positions of the earth in aphelion and perihelion, furnish data which enable us to compute with almost positive certainty the minimum temperature of that part of the envelope of the sun the radiant heat of which we receive.

Experienced observers are well aware that it but seldom happens on the eastern portion of the American continent, that the atmosphere is sufficiently free from vapors at the summer solstice to present a perfectly clear sun. During the period of my investigation of solar heat, the weather at midsummer has not been favorable for actinometer observations. I have accordingly been compelled to compute the sun's intensity at the summer solstice from observations made during certain periods before and after the passage of the aphelion. The solar calorimeter, which indicates the sun's dynamic energy very accurately, has been of much service in corroborating and checking the computations alluded to. Future observations in more favorable localities, may possibly call for some modification, but not of sufficient magnitude to affect the question practically. The mean of the several observations which I have made, and of the computations based thereon, is somewhat over 6 deg. Fahr. increased intensity of solar radiation consequent on the diminution of the earth's distance from the sun during our winter solstice. The eccentricity of the earth's orbit, as before stated, is 0.01679; the ratio of greatest and least distance from the earth to the centre of the sun will accordingly be as 1.01679 to 0.98321. The temperatures being inversely as the square of the distances from the centres of spheres uniformly heated at the surface, we ascertain, by squaring the amounts last presented, that the ratio of temperatures on the ecliptic at our summer and winter solstices will be, in round numbers, as 966 to 1033. The actinometer observations, recorded in a previous article, prove that the maximum solar intensity on the tropic of Cancer, at midsummer, is 67.2 deg.; while the diagrams furnished at the same time, show that the loss of intensity of the sun's rays in their passage through the atmosphere, on the ecliptic, is 0.207 or 17.64 deg. Accordingly, the temperature produced by solar radiation at the boundary of the atmosphere when the earth passes the aphelion (summer solstice), will be 67.20 deg. + 17.64 deg.=84.84 deg. Fahr. The square of the distances between the sun and the earth during the summer and winter solstices being, as already stated, in the ratio of 1033 to 966, we ascertain by analogy that the temperature at the boundary of the atmosphere will be 90.72 deg. when the earth passes the perihelion (winter solstice), viz., 966 : 1033=84.84 deg.: 90.72 deg. Hence, the increase of intensity of solar radiation caused by the eccentricity of the orbit, and the consequent approach of the earth towards the sun during the winter will be 90.72 deg. − 84.84 deg.= 5.88 deg. Fahr. The readers of "Outlines of Astronomy" are aware that Sir John Herschel assumes that 23 deg. Fahr. is the least variation of temperature which can be attributed to the variation of the sun's distance. The reasoning on which this remarkable assumption is based is incompatible with the ascertained intensity of the sun's radiant heat, as will be shown hereafter.

The frontispiece of the present number represents an instrument for ascertaining the temperature of the sun. At first sight it will appear futile to undertake to measure temperature at a distance of 90,000,000 miles; but in view of the fact that the sun has been weighed by an instrument consisting principally of four leaden balls less than 10 in. in diameter, the attempt cannot justly be deemed absurd. The reader will remember that in the celebrated Cavendish experiments, afterwards repeated by Baily and others, the weight of the earth—on which the weight of the sun is based—was ascertained by measuring the attractive force of two spheres of lead weighing 174 lbs. The delicate nature of the experiment may be inferred from the fact that the ascertained attractive force was found to be only $\frac{1}{43\,0\,0}$ of a grain. The illustrated device by means of which the temperatnre of the sun may be measured, involves no such nicety.

Before entering on a description of the solar pyrometer, it will be necessary to call to mind the previous argument, which demonstrates that the law relating

to the radiant heat of spheres, is also applicable to concave spherical surfaces if the substances exposed to their radiant heat be placed in the centre of curvature. The argument referred to, also proved that the temperature produced by the radiant heat transmitted by concave radiators of equal temperatures, at equal distances, is directly as their areas. Melloni and Leslie's experiments, conducted in the presence of the disturbing influences of atmospheric air, not being deemed sufficiently accurate to prove the correctness of the assertion referred to, the construction of the pyrometer now presented has been so modified as to prove conclusively that under the stated conditions the temperatures correspond exactly with the areas.

The frontispiece represents a longitudinal section through the vertical plane, and a photographic perspective of the solar pyrometer, modified for the purpose alluded to. As will be seen by referring to the longitudinal section, the instrument is composed of four principal parts: 1. The heater, consisting of a cylindrical vessel placed vertically, having a spherical bottom and open top; an enlargement representing a truncated cone being formed near the middle, the ends of which are concave and spherical. 2. A conical vessel surrounded with a double casing secured to the base of the central enlargement of the heater. 3. A cylindrical vessel secured to the opposite end of the said enlargement, also surrounded with a double casing. 4. A furnace enclosing the lower end of the heater. The spherical concavity at the base of the conical enlargement of the heater, the radius of which is 18 in., presents an area of 78.84 square inches. The opposite spherical concavity, the radius of which is 9 in., presents an area of $\frac{78.84}{4} = 19.71$ sq. in., its diameter being very nearly 5 in. Thermometers are applied at the *foci* of the spherical concavities, their bulbs being so arranged that only one-half of the area is exposed to the radiant heat, the other half being surrounded by a non-radiant substance. It is proper to observe that thermometers employed in measuring the intensity of radiant heat, must be so arranged that no part of the bulb which is not acted upon by the heat rays projected from the radiator, should be permitted to part with any of the heat received, excepting by radiation in the direction of the radiant body. This is an indispensable condition which must be fulfilled in order to secure a correct indication. Accordingly I have resorted to various expedients to prevent loss of heat from the shaded side of the bulb, and find that surrounding the latter with a casing of burnished silver provided with a suitable opening on the front side, is the most efficient means of attaining the object. The cylindrical as well as the conical chamber of the pyrometer containing the thermometers, are connected by suitable pipes with an air-pump by means of which the air is carefully withdrawn; a current of water being circulated through the double casings when the instrument is in operation. With reference to the heater, it is only necessary to observe that, being open at the top and charged with pure water, it will be maintained at a constant temperature of nearly 212 deg. when the furnace is in action.

The principle of my solar pyrometer is that of ascertaining the intensity of the heat of the sun by comparing the temperature produced by the radiant heat of a concave spherical radiator of 10 in. diameter, at a distance of 18 in. from its face, with the temperature produced by the radiant heat of the sun, a sphere of 832,584 miles in diameter, at a distance of 91,430,000 miles from its centre. The radiant heat in both cases is transmitted through ether; in the former to the surface of the bulb of a thermometer; in the latter to the boundary of the earth's atmosphere. The law which governs the propagation of radiant heat through ether, is as absolute as the law of gravitation, whatever be the distance; hence the pyrometer under consideration, in which the radiant heat is propagated a distance of 18 in. through ether, is as competent to determine the temperature of the sun as the Cavendish leaden spheres acting at a distance of 8.85 in. to determine his weight. The chances, however, of an exact determination are greatly in favor of the pyrometer. In the first place, while the area of the concave radiator of the pyrometer is to the area of the great circle of the sun as $1 : 2871 \times 10^{16}$, the weight of the attracted vibrating leaden ball employed in the Cavendish experiments is to that of the weight of the earth as $1 : 7617 \times 10^{21}$, thus showing a

difference of 1 : 265,000 in favor of the pyrometer. Besides, the difference of distance through which the radiant and the gravitating forces act, is in favor of the pyrometer, in the ratio of 18 to 8.85. But these considerations, however important on account of the greater difference of the magnitudes involved, may be considered trifling in comparison with the directness of the means by which the solar pyrometer solves the problem, contrasted with the indirectness, exceeding complication, and nicety, involved in the Cavendish experiments. In the solar pyrometer we only require a correct indication of the temperature of the radiating concave spherical surface, and of the temperature transmitted to its focus; together with an accurate measurement of the distance of that focus, and of the area of the radiating surface. These points being determined with exactness, we may enter upon and carry out our computation without introducing a single correction. How different the Cavendish experiment, with its numerous disturbing elements depending on barometric and thermometric conditions and changes, all influencing a gravitating force amounting to only $\frac{1}{43000}$ of a grain! We lack space to present an account of the almost insuperable difficulties which were surmounted in those remarkable experiments, which, for ingenuity, care, and perseverance stand unequalled in the annals of physics. This brief allusion, however, to experiments which satisfactorily determined the weight of the earth, and thereby the weight of the great central body of the planetary system, has been deemed appropriate as a contrast. The directness, facility, and certainty of measuring the temperature of the sun by the means we are now considering, would scarcely be appreciated without calling to mind the method adopted for ascertaining its weight.

Referring to the construction of the solar pyrometer and its apparently ponderous character, practised experimentalists are aware of the difficulties of conducting investigations in which a perfect and continuous vacuum is wanted; when heat and cold, as in this case, are brought into close proximity, weight and substantial proportions, they know, cannot be avoided. They also know that the indispensable condition in the solar pyrometer, of maintaining a constant temperature of the concave spherical radiator, is not easily fulfilled; and that nothing short of an *open* heater containing a fluid which readily evaporates, and the application of an excess of heating power, will accomplish the object in view. Evidently the loss occasioned by radiation cannot be exactly made good by the most delicate mechanical contrivance; but by applying an excess of heat in the furnace, the fluid which regulates the temperature of the radiator will be prevented from falling below the boiling point; and since the heater is open, the steam formed will carry off superfluous heat, and thus maintain the fluid at the desired uniform temperature. The exhausted chambers which contain the thermometers, must of course be maintained at a constant temperature, the least fluctuation being fatal to accurate indication of the intensity of the heat transmitted by the radiators. In order, therefore, to keep up the necessary constant temperature, a current of water (obtained from the street main) is circulated through the double casings which surround the exhausted chambers. By this expedient, in connection with the perfectly uniform temperature maintained in the heater, it has been easy to ascertain with critical nicety the temperature produced by the radiant heat transmitted from the spherical radiator to its focus. Regarding area and curvature, accurate workmanship alone will insure what is requisite; but the position of the thermometer, the placing it at the proper distance with reference to the focus, involves many considerations; indeed this is the most difficult point connected with the management of the solar pyrometer. Obviously it would not be correct to place the centre of the bulb in the focus of the radiator, as that would bring the face of a bulb of $\frac{1}{2}$ in. diameter $\frac{1}{4}$ in. in advance of said focus; nor would it be proper to carry the bulb so far back that its face would intersect the focus. The focal distance being 18 in., it will be found that placing the bulb half way between these two positions will cause an error of fully 0.007. Conflicting indication, it should be observed, is unavoidable, since every part of the exposed half of the bulb cannot be equidistant from the face of the concave radiator; but this notwithstanding, there *is* a distance at which the indi-

cation of the thermometer will be precisely the same as if its entire contents were concentrated in the focus of the radiators. This position has been determined, but an account of the process would occupy too much space.

In view of the foregoing explanations, and granted that we know the distance and diameter of the sun, I assert that the solar pyrometer enables us to ascertain the sun's temperature.

The hitherto accepted doctrine, that the intensity of radiant heat is directly as the area of the radiators, for equal distances, was shown in a previous article to be fallacious, because the radiant heat transmitted from the boundaries of plane radiators, *when enlarged*, becomes enfeebled by distance and the consequent dispersion of the heat rays, in the ratio of the squares of the distance between the radiator and the recipient of the radiant heat. The solar pyrometer being based on the assumption that the intensity of the radiant heat transmitted from concave spherical surfaces is directly as the areas of such radiators, it was deemed necessary to establish the correctness of this assumption, and for that purpose the solar pyrometer has been modified as before mentioned. The lesser radiator attached to the conical enlargement of the heater (see illustration), and the cylindrical chamber enclosing the same, have accordingly been added to the instrument. It has already been stated that the area of the spherical radiator enclosed by the conical chamber is exactly four times greater than that of the opposite radiator, and that the radius of the latter is exactly one-half of the radius of the former. The demonstration already referred to established the fact that in concave spherical radiators presenting equal areas, the radiant heat transmitted is in the inverse ratio of the square of the distances if the substance exposed to the radiant heat be placed in the focus of the radiator. It follows from this demonstration that, for equal area, the intensity of the radiant heat transmitted to the focus of the lesser radiator, will be four times greater than the intensity of the radiant heat transmitted to the focus of the large radiator. But the area of the latter is exactly four times greater than the area of the former, while the thermometers in both chambers are exposed to the radiation of surfaces heated by the same medium, and therefore of precisely equal temperatures. At the same time these thermometers radiate against surfaces maintained at a constant temperature, by the reliable expedient of employing a powerful continuous current of water. Consequently, if my assumption be correct, the enclosed thermometers, although exposed to radiators of different area, should indicate precisely equal temperature. Actual trial showing that such is the case, the correctness of my assertion, that the intensity of radiant heat transmitted to the *foci* of concave spherical radiators of equal curvature is directly as their area, must be accepted as fully established.

The leading features of the solar pyrometer having thus been explained, I will now state briefly the result of an experiment made while the atmospheric pressure was balanced by a 29.91 inch column of mercury, the temperature of the water in the heater being precisely 212 deg. Besides the advantage of a definite indication of heat, the temperature of the current of water circulated through the casing surrounding the exhausted conical chamber did not fluctuate at all during the experiment; the thermometer inserted in the exit pipe continuing to indicate steadily 48.1 deg. Consequently, before the fire was applied in the furnace, the enclosed thermometer, the surrounding chamber, the water contained in the heater, and the radiator, were all brought to a temperature of 48.1 deg. The result of applying fire to the furnace and bringing the water in the heater to the boiling point was that of increasing the temperature of the spherical radiator from 48.1 deg. to 212 deg., difference=163.9 deg.; the temperature of the focal thermometer at the same time increasing from 48.1 deg. to 60.3 deg., difference=12.2 deg.

Experiments instituted to determine the important question of radiant power have failed to show that the heat-rays emitted by a metallic surface, prepared as in the solar pyrometer, have less energy in proportion to the temperature of the metal than the heat-rays emanating from incandescent carburetted hydrogen in proportion to its temperature. Indeed, the experiments prove that, relatively, less energy is possessed by the heat-rays of the latter, transmitted through air,

than that possessed by the rays from the metallic surface transmitted through a vacuum. No doubt the difference is owing to the refrigerating effect of the surrounding air during the experiments with the flame. Trials to ascertain the radiant power of incandescent gases, within a vacuum, have not been attempted on account of the intricacy involved in constructing an apparatus capable of maintaining a solid flame within an exhausted vessel. The question is, however, not of vital importance, as it is possible to subject the correctness of the indications of the solar pyrometer to a more rigorous test than that of comparing the radiant power of metallic substances and incandescent gases. Our knowledge of the distance and diameter of the sun, and of the intensity of solar radiation at the boundary of the earth's atmosphere—demonstrated in a previous article—enable us to calculate with almost perfect accuracy the temperature of the sun, exclusive, of course, of the energy which is lost during the passage of the rays through the solar atmosphere beyond the point of maximum intensity.

Before applying this test, let us first determine the temperature of the sun in accordance with the indications of the solar pyrometer. As the principle of the instrument calls for the employment of a concave radiator of spherical curvature, it will be evident that in comparing its indication with solar radiation, we must not overlook the fact that the sun, in place of presenting a concave spherical surface, the focus of which is situated at the boundary of the earth's atmosphere, presents a convex semi-spherical face. In consequence of this—the sun being 852,584 miles in diameter—his limb will be 426,292 miles further off than the nearest point of his face. The eccentricity of the earth's orbit being 0.01679, while the mean semi-diameter is 91,430,000 miles, it follows that during the summer solstice the distance from the earth to the centre of the sun will be 92,964,800 miles. Deducting the radius of the sun, we ascertain that the distances to the sun's limb, and to the centre of his face, are respectively 92,964,800 and 92,538,500 miles. Inverting the square of these distances, it will be found, therefore, that the intensity of radiation from the limb of the sun, compared with the central part, suffers a reduction of 0.0086. The temperature at the boundary of our atmosphere being 84.84 deg., it will thus be seen that the reduced intensity under consideration amounts to $0.0086 \times 84.84° = 0.51°$ Fahr. The observed diminution of the intensity of the radiant heat emanating from the limb of the sun being more than this, it will be seen that we may, without material error in our calculations, regard the entire surface represented by the area of the great circle of the sun as being equidistant—92,964,800 miles—from the earth.

It results from previous demonstrations that the temperature of spherical radiators transmitting equal intensities to their *foci*, are inversely as the square of the sines of half of the angles which they subtend, that is, the angles formed by the axis of the radiator and the heat rays projected from the circumference to the *focus*. We know from previous explanations that, owing to the great distance in connection with the diminished intensity of the rays emitted by its limb, the radiant power of the sun will be identical with that of a spherical radiator whose focus is situated at the boundary of the earth's atmosphere. Consequently, as the spherical radiator of the solar pyrometer, the temperature of which is 163.9 deg., transmits to its focus an intensity of 12.2 deg., we are enabled to calculate what temperature the sun must possess in order to transmit an intensity of 12.2 deg. to the boundary of our atmosphere. The angle subtended by the sun is 32 min. 1 sec.; that subtended by the radiator of the pyrometer 32 deg 15 min., the ratio of the square of the sines of half of these angles being 1 : 3567.7. Accordingly, the sun, in order to produce by its radiant heat a temperature of 12.2 deg. at the boundary of the atmosphere of the earth, must possess a temperature 3567.7 times greater than that of the spherical radiator of the pyrometer. This latter temperature being 163.9 deg., that of the sun cannot be less than $3567.7 \times 163.9 = 584746$ deg., in order to transmit an intensity corresponding with a thermometric interval of 12.2 deg. on the Fahrenheit scale. But solar intensity at the boundary of our atmosphere, as demonstrated by my actinometer observations, is 84.84 deg., hence $\frac{84.84}{12.2} = 6.95$ times greater than that transmitted by the radiator of the pyrometer to its focus. The temperature

of the sun, therefore, cannot be less than $6.95 \times 584746 = 4{,}063{,}984$ deg. Fahr.

It will be recollected that the previous demonstration relating to the sun's temperature, established with as much certainty as any proposition in the "Principia," that the temperature produced by the radiant heat transmitted by a sphere of uniform temperature at the surface, is to the temperature of the sphere itself inversely as the square of the radius to the square of the distance from the centre to the point exposed to the radiant heat. The distance between the sun and the earth at the summer solstice being 92,964,000 miles, we find by dividing this distance by the sun's radius, 426,292 miles, that the ratio of distance and radius is 218.1: 1, and hence the ratio of the squares, as 47567: 1. Consequently, the temperature of the sun must be 47,567 times greater than the temperature produced by solar radiation at the boundary of the earth's atmosphere. That temperature being 84.84 deg., the sun's temperature cannot be less than 47567×84.84 deg.$=4{,}035{,}584$ deg. Fahr. Thus the previously demonstrated temperature of 4,063,984 deg. Fahr., based on the indications of the solar pyrometer and the subtended angles, differs only 0.007 from the computations just presented. The methods by means of which these results have been reached differing entirely, each being founded on sound physical and mathematical principles, we cannot reasonably question the reliability of the determination, although the established temperature is inconceivably high. Nor can it be questioned that the actual temperature at the point of maximum intensity is still higher, since the rays in passing through the outer strata must suffer a loss of energy corresponding with the force expended in creating the observed currents in the solar atmosphere. Referring to these currents, the extraordinary rapidity of which, on dynamic grounds, is incompatible with great density or weight, it is proper to call attention to the exceeding lightness of the solar atmosphere, resulting from the high temperature we have demonstrated in conjunction with the small specific gravity of hydrogen. Both obviously contribute to reduce in a very high degree the density of the superincumbent gases, thereby neutralizing the attraction of the immense mass of the sun. Indeed, it may be shown by an easy calculation, that owing to the high temperature—sufficient to expand atmospheric air 7,000 times—together with the small specific gravity of the medium itself, a depth of solar atmosphere of 50,000 miles inside its boundary, will exert no more pressure than the earth's atmosphere, nothwithstanding the superior attraction of the sun's mass. Let us examine this subject briefly. Lockyer assumes that the sun's atmosphere extends 80, 00 miles above the visible surface. Now, although we may fall short in our estimate of the sun's maximum intensity in consequence of the unknown amount of retardation suffered by the rays, there is no difficulty in determining the temperature at the point which terminates the solar atmosphere, since beyond the latter the rays are not subjected to any appreciable loss of energy. Adding, then, 80,000 miles to the radius of the sun, we ascertain that the diameter of the sphere forming the boundary of the solar atmosphere is $852{,}584 + 160{,}000 = 1{,}012{,}584$ miles. A sphere of such diameter subtends an angle of 38 min. 2 sec. The radiator of the solar pyrometer, it will be recollected, subtends an angle of 32 deg. 15 min. The ratio of the sines of half of these angles is 1: 50.22; and therefore the ratio of their squares, 1: 2522.04. Accordingly, the temperature at the boundary of the sphere under consideration (1,012,584 miles in diameter) will be 2522.04 times greater than the temperature of the radiator of the pyrometer, viz., $163.9° \times 2522.04 = 413{,}362°$ Fahr. But the recorded observations and experiments show that the temperature produced by solar radiation at the boundary of our atmosphere is 6.95 times greater than that transferred by the radiator of the pyrometer to its focus; hence the temperature will be $6.95 \times 413{,}362° = 2{,}872{,}865°$ Fahr. at the point where the solar atmosphere terminates. If, in place of basing our computation on the indication of the solar pyrometer, we adopt the mode applicable to spheres uniformly heated at the surface, the temperature at the boundary of the solar atmosphere will, on grounds before explained, be reduced 0,007, hence 2,852,783 deg. It will be preferable to adopt 2,872,865 deg. on the supposition that future actinometer observations in localities where the sun is clear, may prove that my determination

of the intensity of solar radiation at the atmospheric boundary, viz., 84.84 deg. Fahr., is somewhat under-estimated.

The mean of the stated temperatures 4,063,984 deg. and 2,872,865 being 3,468,429 deg., we may safely assume that the mean temperature of the solar atmosphere between the point of maximum intensity and the termination of the distance of 80,000 miles from the visible surface of the sun, assumed by Lockyer, exceeds 3,468,429 deg. Fahr.

Our space only admits of an allusion to the speculations and calculations which have been published of late by certain savans relative to solar temperature. Among these, Zöllner's calculations may be mentioned as the most singular, being based on the height of the observed solar protuberances. Practical men who have witnessed the explosions in closed reverberatory furnaces, which take place when a dense mass of incandescent coal gas, resting on the fused metal, is suddenly ignited by the admission of oxygen, will probably attribute the solar protuberances to a very different cause from that imagined by Prof. Zöllner. They will assert that the observed explosions in the solar atmosphere are quite possible without sending up gas from a depth of 139 geographical miles through the "ausströmungsöffnung," supposed by the German physicist. The reader may have noticed that some of the savans alluded to have attempted to set limits to solar temperature on chemical and dynamic grounds, insisting that the temperature of the sun is under 60,000 deg. Fahr. All such speculations are futile, in view of the fact which we have established, that a heated sphere subtending an angle of only 32 min., at a distance of 90,000,000 miles, cannot, unless raised to a temperature of several millions of degrees, transmit radiant heat sufficiently intense to cause an elevation of temperature 84 deg. Fahr. at the stated distance.

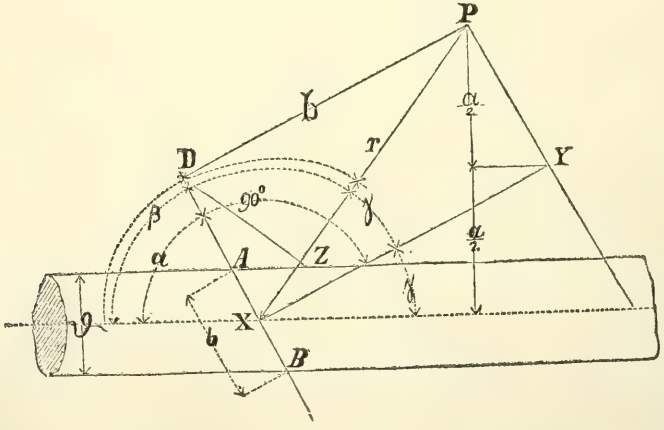
A SIMPLE FORMULA FOR DETERMINING THE RESISTANCE OF AXLES.

By H. VON REICHE.

Translated from "Zeitschrift des Vereins Deutscher Ingenieure."

Many learned men have chosen "compound resistance" of flexion and torsion, as the subject of their investigations; but their explanations have been so elaborate that they have not been read by practical men, and their results have been so complicated, that they will never be applied.

The ordinary process is to calculate



the dimensions of axles first with reference to torsion, and then with reference to deflection; and then, by a sort of *feeling*, to select a diameter larger than the greatest computed. Engineers who are not satisfied with this method generally construct an approximate formula from the cases that come under their observation;

and the various formulas found in their note-books are the best evidence that the requirements of practice in this direction have not yet been satisfied.

The writer had often attempted to construct a simple formula for compound resistance, but had as often been compelled to reject the result. In editing his "Maschinenfabrikation" he took up the formulas most in use with a sort of resignation; but, alarmed by their great number and by the abundance of typographical blunders, he dropped them; the frequent attempt was then repeated and with a perfectly satisfactory result, since the formula deduced is easy and exact in application. Indeed the process is so obvious and natural that it is not easily forgotten.

In the figure the direction of the force P acting on the axle is supposed to be perpendicular to the plane of the paper; let X be the point at which the strain is the greatest. Experience shows that axles subject to both torsion and breaking always break obliquely, as along A B.

Of the sections passing through X it is plain that the breaking section must be that

(1.) Which receives the greatest strain, and in which, consequently, the force P acting with a lever-arm h perpendicular to A B, and acting at Y, is a minimum;

(2.) And which receives at the several points of a line through X, parallel to the force, torsional strains, such that they are in equilibrium with the torsion moment $P \times a$.

Let the breaking modulus for the section $\frac{\pi}{32} D_3 = Q$.

The torsional, $\frac{\pi}{16} D_3 = Q_p = 2\,D$.

r = the absolute lower arm of P.

β = its angle with the axis.

a = the angle of the breaking section with the axis.

$$\gamma = \frac{180 - \beta}{2}.$$

S = the absolute total strain at X.

Then to satisfy (1) we must have:

$$P h = \frac{\pi}{32} b\, D^2 . S,$$

$$D = b \operatorname{Sin} a.$$

$$h = r \operatorname{Sin} (\beta - a).$$

$$\text{Hence } P = \frac{S \frac{\pi}{32} D_3}{r} \cdot \frac{1}{\operatorname{Sin} a \operatorname{Sin} (\beta - a)}$$

must be a minimum, and consequently

$$Y = \operatorname{Sin} a \operatorname{Sin} (\beta - a)$$

must be a maximum.

Differentiating with reference to a, and making the differential coefficient equal to zero, we have

$$\operatorname{Sin} a \operatorname{Cos} (\beta - a) = \operatorname{Cos} a \operatorname{Sin} (\beta - a)$$

$$\therefore \beta = 2\,a.$$

Substituting, we have

$$P . r \operatorname{Sin}^2 \frac{\beta}{2} = \frac{\pi}{32} D^3 . S.$$

To determine whether condition (2) is satisfied:

The total strain S is composed of a breaking strain

$$S_b = \operatorname{Cos} \gamma$$

and a torsional strain

$$S_t = S \operatorname{Sin} \gamma:$$

Transferring P to Y by supplying two two equal opposite forces, the force P is balanced; since

$$P h \operatorname{Cos} \gamma = Q\, S \operatorname{Cos} \gamma.$$

Half the moment of tension is destroyed by the breaking strain, since

$$P \frac{a}{2} P h \operatorname{Sin} \gamma = Q\, S \operatorname{Sin} \gamma.$$

But since the strain S Sin γ because of torsion acts *round* the axle, it resists a torsion.

$$Q_t\, S \operatorname{Sin} \gamma = 2\, Q\, S \operatorname{Sin} \gamma = P a;$$

that is, the axle is in equilibrium with reference to torsion, and condition (2) is satisfied.

The formula for P may be simplified. Instead of measuring the absolute arm r, the line P Z may be measured. The length of this line is $r = \operatorname{Sin}^2 \frac{\beta}{2}$; and the point Z is found by drawing a perpendicular from D to the line P X. Hence by bisecting the angle β and drawing three lines, the length of P Z is found; putting h for this we have the easy formula

$$P . h_1 = S . Q.$$

MR. J. L. Booth, Rochester, N. Y., has invented a new rail, which consists of a compound, formed by first rolling the cap and base separately, and then applying them together and passing them together through a rolling or compressing machine, whereby they are firmly united, and without being heated for the purpose.

SUBMARINE TORPEDOES.*

From "The American Artisan."

The Monitor type of war-vessel has proved to be the most formidable, and, so far as invulnerability is concerned, the most perfect; presenting the least surface of exposure to the shot of an antagonist, and therefore being the more readily protected with armor of almost any required thickness. These facts were practically demonstrated during our late war. Since that time other nations, though slowly, are finding out the formidable nature of these vessels, and cannot spend many more millions on their towering broadside vessels before they will be compelled to adopt the Monitor system.

The folly of trying to successfully employ a floating fort has just been demonstrated in the sad loss of the British iron-clad and turreted ship Captain. A heavy lurch in an ordinary storm, and the top-heavy craft went down—a coffin with five hundred souls inclosed!

To John Ericsson belongs the glory of having constructed the most perfect war-vessel afloat, either for offence or defence. A single shot from a 15-inch gun, fired discretionally from any of our later-built monitors, can be made to penetrate with sad havoc some part of any foreign-built vessel-of-war afloat.

With our monitors, our heavy guns will also be imitated—and we must be equal to the emergency arising therefrom. To accomplish this, we may rely, as it is, upon our success above water, but it will be necessary to turn our attention to operations below the surface, and the best means of submarine attack and defence call loudly for attention.

As regards "submarine warfare," we seem yet to be comparatively in the dark, notwithstanding many improvements have been developed in it during the past eight years. Our Government has adopted a system which have worked well in experiment, and which will, no doubt, be very effective in actual practice; but its operation requires close contact with the enemy, and also involves the use of expensive and strong machinery. The object to be attained is the destruction of an enemy with as little danger to ourselves as possible. Water is an element through which we can direct greater masses of explosives than is possible in the air, although at a sacrifice of velocity; 200 or 300 lbs. of powder under a vessel's bottom will unquestionably be more serviceable than the same number of tons of explosives consumed in the ordinary manner above the water-line. The devices through which this result is to be brought about are known as "torpedoes." These will provide the most effective and deadly agencies of the warfare of the future, and, though apparently in their infancy, they have become necessary both in the military and the naval service. The protection of a harbor lies not in its forts (be they manned with the best artillery and men), but in the arrangement of its torpedoes and "infernal machines," placed where the adversary, if he comes, must come to his own destruction.

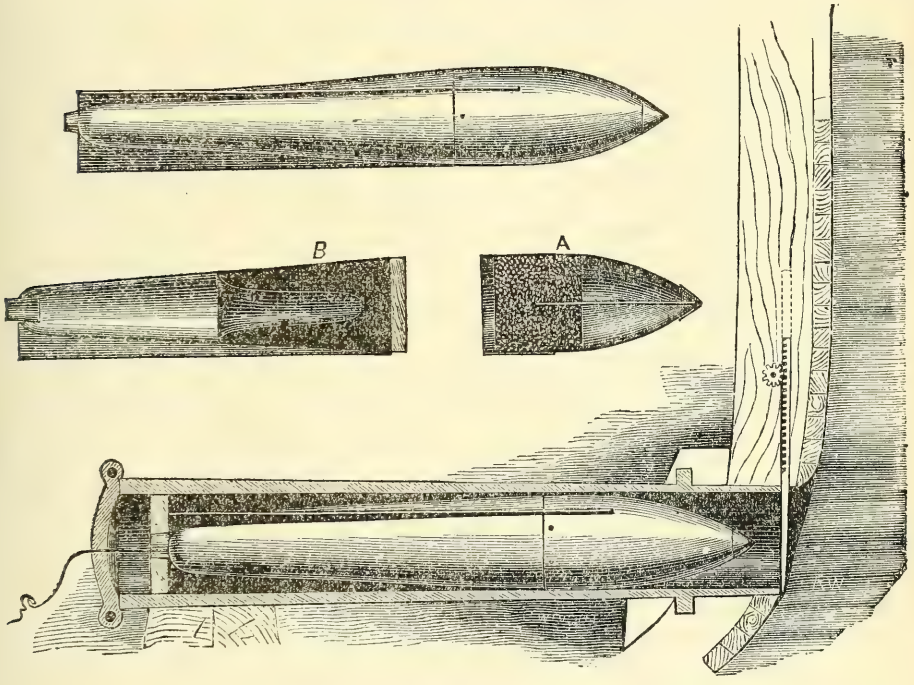
"Torpedoes are supposed to have been first devised by David Bushnell, of Connecticut, about the year 1776. His first use of them was from a submarine boat known as the American Turtle, from its close resemblance to that reptile. With this boat, which could be completely submerged, and which the inventor propelled by an oar, worked as a scull, he would guide himself to the ship which he intended to destroy, screw his torpedo (a tank containing about 150 lbs. of powder) into her bottom; release the catch of the clock-work, which was contained within the powder and connected to a gun-lock trigger, cast off his boat, and return to shore, rising to the surface by forcing, with a pump, the water from his craft. The clock-work was arranged to run a certain time, when the trigger would be released and the charge exploded. Many attempts were made to destroy British vessels with this contrivance, but never with success.

In about 1805, Robert Fulton made similar experiments, but without the assistance of a "turtle;" his success was but little better than Bushnell's. In 1810, he published a work entitled "Torpedo War and Submarine Explosions."

* Abstract of a paper read before the New York Society of Practical Engineering, by Robert Weir, C. E.

The next use of torpedoes was in the Crimean war, where the Russians used them to good purpose, not so much in the results of actual explosion as in their demoralizing tendency. In our own late war the rebels employed torpedoes with marked success in many instances. At first, we were inclined to condemn them; but we soon found that we must fight the enemy with his own weapon; and so we became case-hardened from the example of our foemen, and their exertions did more towards the advancement of this branch of military art with us than we could have ever gained without such an unpleasant incentive. A very interesting and instructive work has been compiled by Lieut. Commander I. S. Barnes, U. S. N., in which are given detailed and illustrated descriptions of all the "infernal machines" which were employed against us during the war, and of some of our own inventions to circumvent the enemy.

Since the close of the war, other nations have realized the great importance of this arm, and have taken the deepest interest in its perfection. The Austrians have invented a projectile which, being propelled by compressed air-working propellers, will regulate its depth in the water by a vertical rudder, worked by hydrostatic pressure; the water acting



upon a diaphragm of india-rubber, which will be compressed or expanded according to the depth of immersion. This action is utilized, so that the rudder can be set to retain a certain position for the torpedo, according to the depth the operator may wish to strike an object. We have had rather indefinite descriptions of this torpedo; the few remarks given above were obtained from an army officer who had witnessed a trial with one of those machines.

A British torpedo known as the "Otter," and invented by John Harvey, of the Royal Navy, has been adopted by the Russians, and is considered of great utility in the British navy. This is a wooden casing strengthened with iron, and containing the shell or torpedo within it; the shape is rhomboid, about 1 ft. wide, 12 ft. long, and 8 ft. deep. A cable is attached to this in such a way that when towed from a vessel it can be made to diverge from her course at any angle within 45 deg. To compel this machine to hug the side of an enemy will require a great excess of speed in the assailing vessel, and would be very clumsy

to manage under any circumstances. England prides herself on being now possessed of a machine which is very sailor-like in its action and well suited to the use of seamen, an estimate of the value of the apparatus with which no fault can be found. A number of "Engineering" in March of this year contains an interesting description of a practical test with this torpedo. A steam-tug was used as the towing craft, being fitted with the needful paying-out apparatus, and Capt. Harvey conducted the operations against the iron-clad Royal Sovereign. In the first part of the operation the vessel remained at anchor, and though doing her best to avoid the torpedo, was struck by it every time at depths varying from 1 to 16 ft., the tug towing the torpedo with about 50 fathoms of line. In the next trial the Royal Sovereign got under way, steaming about 8 knots, the tug making about 11 knots, and in the six trials made every torpedo struck and the caps were exploded.

John Ericsson has brought up some later ideas in regard to submarine warfare, which are worthy of much consideration. One proposition is that the torpedo shall be driven by two propellers working in opposite directions; the shaft of the outward propeller revolving inside the other. The motion given to these shafts would be through rotary engines, driven by air supplied from the ship through a flexible tube which is towed out from the vessel's side as the pressure works the propellers. The torpedo will be guided by a greater or diminished allowance of air as the tube is reeled off. This is practicable, but the necessary connections of the apparatus are cumbersome and liable to derangement. Mr. Ericsson's last proposition is to throw elongated shells from 15-inch guns at moderate ranges, letting them dip into the water before reaching the vessel aimed at, and continuing their course to strike the enemy several feet below the water-line and explode. These shells are to contain 200 lbs. or more of dynamite, and their range would be about 1,500 ft. If this is practicable, we only need gunners with thoroughly practised and educated eyes to calculate their distances to a nicety. The details of slow-burning charges and safety in the use of dynamite are expected to be solved, as also the proper direction of the axis of the shell.

In 1864 I was attached to one of the vessels of our wooden blockading fleet off Mobile Bay, and was sent from there to Pensacola to construct some torpedoes to be used from the bows of our ships—a temporary arrangement, which was invented from the necessity of the hour, our fleet being constantly exposed to attack from formidable rebel iron-clads. It was here that I made my first experiment with a projectile, the principle of which, and the experiments carried on with the apparatus, I now propose to describe.

This torpedo is really a submarine rocket, a slow-burning powder being used to supply the propelling power, while the construction may be justly characterized as plain and simple, the device being composed of only two parts, viz.: the exploding shell, or torpedo proper, and the rocket, or propelling shaft. Both parts can be made of copper, zinc, sheet-steel, or thin boiler-iron. In the engraving A is the torpedo, or exploding part of the projectile. This is shaped like an ordinary rifle-shell, to present a surface of least resistance to the water. The apex, when the apparatus is in use, consists of an easily ignited percussion fulminate, covered with a thin or film-like coat of copper, covering several inches of the point of the shell, so that contact with any part of the front will ignite the charge. The shell is then filled with the exploding powder through a hole in its base. B is the rocket, or shaft-projector—a hollow, tapering shaft made of thin, strong material, to be filled with slow-burning powder. On the outside, and at equal distances apart, are three wings or keels, set on the same line as the axis of the projectile. The small end of the shaft has a contracted opening, through which the gas of the rocket-powder in the chamber is to act in propelling the torpedo. This shaft is loaded with a large rocket, or the rocket-powder is rammed into it, as in a rocket case, leaving a central opening, of large surface, for the burning powder, which is mixed with a greater proportion of sulphur to insure the necessary action.

When filled, the large end is securely stopped with a carefully-fitted plug or

sabot of wood, and it is then set into the lower rim of the shell, where it fits snugly. It can be secured in this position by screws, which join all parts together with strength. The weapon is now ready for use; and, as it must be projected from below the surface of the water, a gun or guide of sufficient strength, and of simple construction, can be secured in the vessel's side or bows 8 or 10 ft. below the water line, as needed. This will have an outboard and inboard, or breech valve. To load, the outboard valve will be closed, and the inboard opened; the torpedo will be carefully run into the chamber to a marked distance. A thick, wooden sabot, with a hole turned in the centre of it, just large enough to receive the projecting tube of the shaft, is then placed against the swell and wings of the instrument, fitting snugly in the bore of the gun, as will be seen by the drawing, and leaving a space of several inches between itself and the inboard valve. A friction primer is now set in the tube connecting with the slow-burning powder; the wire from this runs through the inboard valve, which is now closed, and the outboard valve is opened, admitting the water freely around the torpedo to the sabot. The instrument is now ready for use. Possibly, it may be necessary to assist so large a body in starting. This can be done by mechanical means. After firing, which is directed from deck, the outboard valve is closed, and the inboard valve opened, allowing the water from the gun to run into the hold of the ship. Another torpedo is placed in position, etc. This operation of loading and firing will consume no more time than has been occupied in its description. The torpedoes being made, and cased ready for use, are stored in the magazine like loaded shells.

Any vessel can be armed with these torpedoes, for the construction of the gun or guide is comparatively simple; the power which forces the projectile from t e gun, being contained in itself, will necessitate but little trouble in handling. One of our monitors, armed with three or four of these guns, could defy the navies of the world. In the very first experiment that was made to test this principle, its success was made apparent. The torpedo was constructed of light pine wood, turned to the shape of a spindle, 25 in. in length, and 3 in. in diameter at the centre, and, being composed of two pieces, was cut away in the inside to admit of ballast and an ordinary government rocket. It was then carefully weighted with lead, making the specific gravity very little more than that of water, so that when it was placed in the water it would slowly settle to the bottom, and still retain a horizontal position. The after or rear part of the spindle was provided with three wings of tin, placed equidistant from each other, and in a true line with the axis of the spindle. It was fired from a wooden-box guide at a depth of 2 ft. below the surface of the water, and where there was but little tide or current, at a target placed 63 ft. distant. The torpedo started almost instantly from its position of rest, and travelled most satisfactorily, making about 12 ft. a second, as it took five seconds to accomplish the distance, striking the target 3 ft. to the left of the centre, and 2 ft. 10 in. below the surface of the water. This excess in depth was attributable to the lightening of the after-part of the spindle by the burning away of the rocket powder, causing that part to lift.

This experiment was followed by numerous others, all of which clearly demonstrated the success of the principle. These projectiles could be used at any distance under 250 yards with effect. A little practice with that short range would enable the operator to be pretty sure of hitting his mark. And for attack against a fleet entering a harbor or otherwise, the range could be unlimited, as the propelling powder is made to last. With this arrangement, a man need not be hoisted by his own petard, as is so apt to be the case where close contact of the operator is required.

It will be seen that the velocity of these projectiles will depend upon their shape and sectional area, as well as the powerful action of the generated gas. They must be well and carefully proportioned, their length being not less than six times the diameter. Torpedoes, for the use of ships, could be made about 18 or 20 in. in diameter, containing from 175 to 200 lbs. of explosive powder; and, for harbor defence, they might be made 2 ft. in diameter. One of this latter diameter would be 12 ft. long, and, being made of scant $\frac{1}{4}$-in. boiler iron, the weight of the entire shell would not exceed 600 lbs.

The displacement of water would be nearly 20 cubic ft., or 1,234 lbs., leaving 634 lbs. for the explosive and propelling powders. 300 lbs. could be used for the generation of the gas, and 340 lbs. for the exploder; but, for harbor defence, nitroglycerine could be used, and thereby reduce the size of the torpedo considerably; and by reducing the size of the shell, and lengthening the shaft proportionat ly, such a mixture could be used as would generate a tremendous pressure of gas for the propelling force, and, by reducing the time of travel to a minimum, insure better results. In some of the experiments which were tried, the velocity attained by this means was astonishing. The projectiles were made of tin, and about 10 diameters in length, with carefully pointed heads of wood—the whole length being 3 ft., and propelled by 20-oz. rockets. They looked like living fish under the water, darting in a true line with as great velocity. To perfect this arm, experiments must be tried on a large scale; possibly they might be made considerably heavier than water and used on the principle of rockets, that is, to start them with an elevation approaching the surface of the water midway in their course to the enemy, and, gradually sinking towards the end of their course, strike and explode.

Their use can certainly involve but little detail in the construction of the guns or guides, for, when the torpedo is ready to be fired, it is no more weighty than water; and to start it, compressed air could be admitted behind the sabot at the moment of firing. This sabot in starting becomes a piston, which receives nearly all the starting pressure. It keeps the water from contact with the gases in the gun, which would otherwise be partly reduced or condensed; and, on compressed air being suddenly admitted, the powder will burn freely, and the inertia of the mass be gradually and delicately overcome. As the sabot leaves the mouth of the gun, it meets water at rest, and the onward motion of the torpedo frees it, when it is free to rise to the surface. The delicate cap on the end of the torpedo will cause the explosion if it strikes at any angle outside of about 30 deg. from its own line of course, so that the enemy may be struck in any position. It is within bounds to say that these torpedoes could be made to travel 36 ft. a second, or at the rate of 25 miles an hour. In this case, if an enemy is 250 yards distant, it would require about 20 seconds to reach her. This tardiness will certainly require some dead reckoning on the part of the operator; but practice will soon give him complete control of the machines, so that, whatever may be the intervening tides or currents, or the swift motion of the enemy's vessels, he would be able to strike home, say 9 times in 10. 300 lbs. of composition, requiring half a minute to consume, would give all the power required for propulsion. However, as I have before stated, the real value of this principle can only be arrived at by practice on a large scale. There might be some minor details to be regulated with reference to the proper regulation of the composition used, generating the propelling gases, but any difficulty in this respect can be easily overcome. In conclusion, I see no reason why every vessel in our navy could not be supplied with this arm in addition to their present batteries, and thereby be enabled to defy all comers. For harbor defence, these torpedoes would do away with the use of forts, for small floating batteries could be anchored at intervals across the entrance. These could be made invulnerable above and below water, and each armed with several of these guns, and, furnished with the calcium light for night work, would render a seaport impregnable.

A very curious influence exerted by heat upon diamonds has been noticed at the works of St. Helen's, recently visited by the British Association. When a diamond is used to cut hot glass the diamond will only last for one day, and it assumes a milky appearance. The diamonds in constant use for cutting cold glass last about three months. Each diamond costs from 35s. to 45s., and is about three times the size of an ordinary glazier's diamond. Hot glass is cut more readily than cold glass.—*Popular Science Review.*

The "Moniteur" comments severely upon the undisturbed Prussian railway communication between Paris and Saverne, and recommends the formation of bodies of men specially charged to destroy the German communications.

LOCOMOTIVE IMPROVEMENT.

From "The Engineer."

Every competent engineer, civil or mechanical, will admit that the locomotive engine, approximately perfect as it is, may yet be rendered better. The civil engineer, indeed, demands that it may be made less damaging to his roads, while the locomotive superintendent earnestly desires to effect a saving in fuel and in the cost of repairs. If then it is admitted by both classes of the profession that improvement is desirable, how is it that the improvement is not effected? It cannot be because constructive skill is lacking. The absence of ingenuity cannot be pleaded as an excuse. The true answer is, that the locomotive is daily undergoing small, almost imperceptible, improvements on the one hand, and, on the other, it must be borne in mind that the locomotive is so nearly perfect in its best form, that the task of making it still better without launching out into a course of costly experiments, for which railway companies have no available funds, is extremely difficult of performance. To use an often quoted illustration of the late Dr. Lardner's, imperfections which will ruin a razor are of no account in a carving knife. It would not be very difficult to make an average carving knife of good steel as sharp as a razor, but it would be impossible to make any razor as much sharper than the average of razors. If the locomotive were not very good indeed it would be easy to make it better; in the fact that it is very good lies the obstacle in the way of further perfection. It is by no means to be assumed, however, that the obstacle is insurmountable. What can be done in the way of effecting economy of fuel in one engine, men ought to be able to do in another. If we can get a horse power for the consumption of 1.5 lb. of coal in the case of the marine engine, we ought to do nearly as well in the case of the locomotive. Certain engineers have shown that it is possible to haul enormous loads without so seriously weighting the driving wheels as to compromise the stability of permanent way. All locomotive designers ought to be able to do the same. If they are competent men, and do not do this, then we must assume that some good reasons exist for the fact. Let us see what these reasons may possibly be; and let us also consider for a moment the direction in which the improvement of the locomotive is most likely to be effected and is most desirable.

The subject may be best dealt with under three heads: Firstly, the locomotive as a steam generator; secondly, the locomotive as a steam user; and thirdly, the locomotive as a vehicle. It is with the last alone that the civil engineer has, strictly speaking, anything to do. It is only as a vehicle that the locomotive destroys permanent way. The question of what it will draw, and the relation which its power of drawing bears to the contour of a line, troubles him but little in determining that contour, because he knows that whatever that contour may be, the mechanical engineer is prepared to supply him with engines to work it with regularity and efficiency.

The first question, then, for consideration is the improvement of the locomotive as a steam generator; and with this alone we shall deal at present; to the others we shall refer at no distant date. There is no room to doubt that the very best locomotives are uneconomical steam generators. The rate of evaporation seldom exceeds 7 lbs. of water to one of coal. In exceptional instances 8 lbs. or even 9 lbs. have been evaporated, or a little more perhaps; but in these cases the boilers have been new, and the surfaces free from deposit. It is unfortunately a condition of the locomotive boiler that the tubes cannot be freed from scale without taking them out; and as it is certain that scale accumulates more or less slowly according to the quality of the water and the care exercised by the drivers, but does still accumulate, the evaporative economical efficiency of every locomotive must fall off year by year, and decrease from what it was at first. Bearing this in mind, it will not, we think, be wrong to assume that the average duty of all the locomotives in England will not greatly, if at all, exceed 6.75 lbs. of water fairly evaporated — not primed — into steam. But this is, as we know, far below the efficiency of other types of boiler. It should not be too much to expect an

evaporation of 8.5 lbs. of water per pound of coal, considering how good the coal is that locomotives usually burn, and the skill of the stokers who attend to its consumption. Is it or is it not possible to obtain this result, not in exceptional cases, but in thousands of locomotives, year after year, and in all parts of the United Kingdom? We fear that the answer must be in the negative. If the past teaches any lesson worthy of notice, we are certain that it cannot be effected so long as the existing type of boiler is retained in its absolute integrity. The horizontal tubular, or locomotive boiler, has undergone an enormous number of modifications, but not one real improvement has been effected. The most highly approved locomotive boiler of the present day is identical with those in use in 1840 in every respect save its dimensions, the quality of its workmanship, and a brick arch in the fire-box. Long grates, combustion chambers, and in the best practice mid-feathers, have disappeared from the railway world. We have nothing left but the approximately cubical fire-box, and a greater or smaller number of brass or iron tubes of a greater or lesser length according to circumstances, running straight to the smoke-box through a cylindrical shell. Not one of the innovations on George Stephenson's designs appears to have obtained any substantial footing in modern locomotive practice. We are, on these grounds, justified in stating that, so long as the modern locomotive boiler is retained, nothing whatever is to be expected in the way of securing a greater economical evaporative efficiency from the fuel used.

The question naturally suggests itself, is it essential that we should continue the use of a boiler admittedly not the most economical? It is not easy to reply to this question. On the one hand, it may be urged that it is possible to work locomotive engines with boilers very different indeed in form; while, on the other, we have the practice of the last thirty years, and of the best mechanical engineers who have perhaps ever lived, in favor of the existing boiler. It is, besides, very difficult to design any other boiler which will comply with the requisite conditions. Where else is there a boiler to be found which will supply us with as much heating surface within a given space? Where is there to be found a boiler at once so easy to make, repair, and keep in order, so safe, so strong, and, all things considered, so cheap? Where is the boiler which admits of such an efficient distribution of weight, is so good-looking —and even good looks are worth considering in designing a locomotive—presents so large an area of water surface—essential to the production of dry steam—and is so easy to fire and attend to in every way? We may answer at once that there is not one in existence. But granting this, it must not be forgotten that it may be possible to design boilers which, differing more or less widely in important respects from the existing boiler, and sacrificing certain of its merits, will nevertheless be better in this, that they will prove more economical as far as the consumption of fuel is concerned. Whether such boilers can or cannot be produced remains to be seen; but it is at all events certain that no locomotive engineer can prove that it is impossible to build a very efficient locomotive with, for example, a vertical boiler. Such a boiler would of necessity be as unlike the ordinary locomotive boiler as possible—and it is for that reason we cite it to illustrate our meaning—but this does not prevent its application to the required purpose. The distribution of weight could be effected with ease; the qualities of the locomotive as either a steam user or a vehicle would remain unaffected; the convenience of firing would be the same as now, cost and weight would remain unaltered. Only two really effective arguments can be brought against a vertical locomotive boiler. The first is, that it is impossible to provide sufficient heating surface of the kind in any suitable vertical boiler; the second is, that a locomotive with a vertical boiler is opposed to all preconceived notions on the subject of locomotive engines. To which we reply, first, that it is by no means certain that a boiler of the vertical type cannot be devised which will contain as much heating surface, within a shell of given size, as any locomotive boiler; and, secondly, that the mere fact that no other boiler than the existing type has been used hitherto in first-class locomotives is no reason whatever why it should be adhered to till the end of time. The question, in short, narrows itself to this, is it or is it not desirable that every

pound of coal we burn in a locomotive should or should not make more steam than it does? The universal reply will be that it is highly desirable that the utmost possible value should be got out of the coal purchased by railway companies. But it is certain that nothing further is to be expected in this way from the existing locomotive boiler. The best men of the day have worked at it since 1840; that is to say, for thirty years; it is as perfect now as it is possible it can be, and yet it is inferior in evaporative efficiency to a host of other boilers. To assert that any further improvement is to be expected is simply to assert that Mr. Ramsbottom, Mr. Beattie, Mr. Cudworth, Mr. Miller, Mr. Johnson, Mr. Sinclair, Mr. Sturrock, Mr. Martley, Mr. Adams, and hundreds of other engineers both in this country, France, Germany, America, etc., really do not know their business. Under the circumstances, we are justified in repeating the assertion that if more steam is to be made per lb. of coal burned we must alter the type of boiler.

It will, no doubt, be urged by certain of our readers that this is a most "unpractical" article. We grant that it is unpractical in the sense that it indicates, under certain conditions, the necessity for innovations in ordinary locomotive practice; but we cannot admit that it is unpractical in any other sense. No one who is well up in his subject, can deny that further improvement in the evaporative efficiency of the existing boiler is a thing not to be expected in the face of modern practice, which is reverting as fast as possible to the oldest and simplest type of boiler, as may be proved by an inspection of the latest engines on the Midland, Great Eastern, London, Chatham, and Dover, Great Northern, Great Western, North London, and many other railways. At the same time greater exertions than ever are being made by locomotive superintendents to cut down coal bills. The question we submit is, not whether it is right and proper for a journal like this to suggest innovations on existing practice, but whether these changes so suggested are or are not likely to secure the desired end, and comply at the same time with the required conditions. And we desire it to be especially borne in mind that in this article we have done nothing more than enforce on our readers the *fact* that no improvement can be expected in the existing locomotive boiler, while we place before them the *suggestion* that a different type of boiler might be designed—if it be not designed already—which would prove more economical in the consumption of fuel, and equally convenient for locomotive purposes. We shall not so far wrong locomotive superintendents as to believe that they are so wedded to their own practice that they can see nothing worth consideration in the idea of others, although these ideas may introduce somewhat novel views on the future of the locomotive engine. We do not put it forward as certain that a different type of boiler would be better than the existing type, but we think it probable; and it is indisputable that designers of locomotives generally should not be deterred from introducing possible improvements simply because they are essentially different from existing practice.

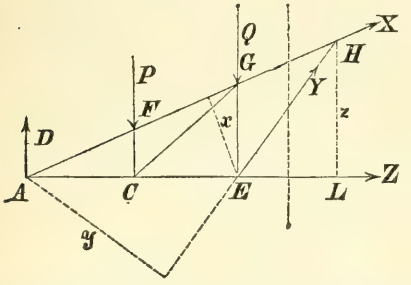
A process for the colorimetric estimation of gold in quartz has been submitted by Mr. Skey, of the Government Laboratory, to the Philosophical Society of Wellington, New Zealand; it is stated fully to meet all requirements, and it does not necessitate the use of quicksilver. The stone to be estimated, after having been thoroughly crushed and calcined, is immersed in a bath of iodine or bromine, and permitted to stand for some time. Slips of Swedish filtering paper are then alternately dipped into the fluid and dried, until the paper is thoroughly saturated with the fluid, after which they are burned in a muffle. If no gold be present the ashes will be white; but 1 dwt. to the ton will give them a beautiful purple color. It is believed that further experiments with odine or bromine baths of known contents of gold will enable the exact proportion of gold to be tested by the colorimetric method.

A Prussian decree has been issued, ordering railway companies immediately to take measures to accelerate the transport of troops and war material. One hour will be allowed for changing from one line to another, and two hours for changing to another company's line. A certain number of telegraphists is to be attached to each army corps.

CALCULATION OF STRAINS IN TRUSSES.

August Ritter, in his Dach-und Brücken-Construction, determines the strains in a roof or bridge truss by applying the principle of static movements. The method is sufficient for finding the strains in ordinary trusses, in lattice, bow-string, and parabolic girders, and in suspension bridges; it is also applicable in the determination of maximum and minimum strains.

Fig. 1.



The general rule may be expressed as follows:

Conceive the construction divided by a section, cutting off only three pieces if possible; and consider the forces X, Y, Z, representing the strains in the several pieces as applied at their intersections.

To determine X, take moments about the intersection of Y and Z; to determine Y, take moments about the intersection of Z and X; for Z, take moments about the intersection of X and Y.

The reactions at the points of support, and the distributed loads at the several points of support, are to be found by the ordinary methods.

Applying this method to the diagram: To find X, take moments about E, giving

$$X\,x - P.CE + D.AE = 0$$
$$X = \frac{P.CE - D.AE}{x}$$

To find Y, take moments about A, the intersection of X and Z.

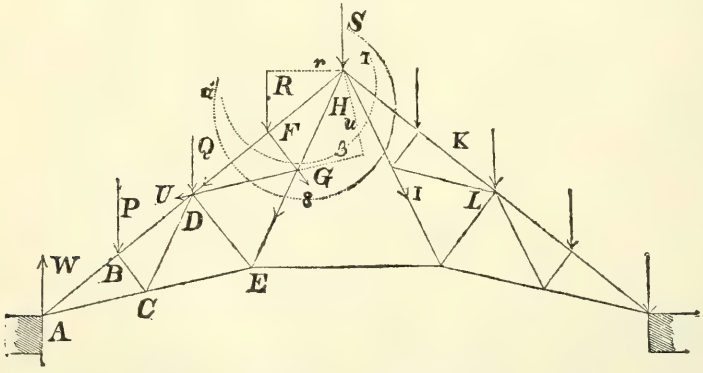
$$-Y\,y + P.AC + Q.AE = 0$$
$$Y = \frac{P.AC + Q.AE}{y}$$

To find Z, H is taken as the centre of moments;

$$-Z\,z - Q.EL - P.CL + D.AL = 0$$
$$Z = \frac{-Q.EL - P.CL + D.AL}{z}$$

This method is adequate in all cases in which the section does not cut off more than three pieces.

Fig. 2.



In complex trusses, as, for example, in Fig. 2, it may happen that there are pieces (F G, D G, D E) which cannot be cut off in this way. In such a case the desired result can be directly obtained, if a section, either rectilinear or curved, can be passed so as to intersect all the pieces that meet at one point.

The strain in V, for example, can be found by passing the section $\alpha\,\beta\,\gamma$ through four pieces and taking moments about H; giving

$$-V.FH - R\,r = 0$$
$$V = -\frac{R\,r}{FH}.$$

The strain U in the piece D G, there-

fore, is found by passing the section $a\,\delta\,\gamma$; giving

$$U\,u - R\,r = 0.$$

$$U = \frac{R\,r}{u}$$

The strains in opposite corresponding parts may be found in the same manner. The strains in the remaining pieces may be found by similar sections, or by sections passing through four pieces, one of which has already been determined.

For example, when U is known, we find for R, S and T, the strains in D F, D E, and C E.

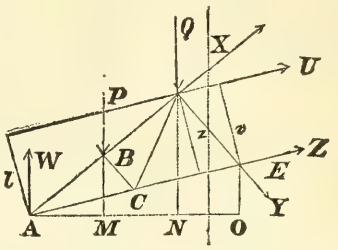
X.D E + U v − Q.N O − P.M O + W. A O = 0 (centre at E).

Y.A D + U l + Q.A N + P.A M = 0 (centre t A).

− Z z + W.A N − P M a = 0 (centre at D).

The advantages of this method hold as well for more complex structures. At first, calculations may be made with the aid of detached diagrams representing

Fig. 3.



the several forces that enter the equation of equilibrium. After a little practice this will be found unnecessary.

Applications of this method will be be given in future numbers.

HISTORY OF THE IRON RAILS UPON THE MICHIGAN, SOUTHERN AND NORTHERN INDIANA RAILWAY.*

About 330 miles of this line were laid down in the year 1851, and operated immediately thereafter with a considerable traffic; but, the Company being then engaged in the construction of branch lines, no accurate account of expenses or renewals was kept until the branches were finished, in 1857, when the length of track owned by the Company, including sidings, was 567 miles.

I have included sidings in the length of track and in all calculations of the averages of wear, because, taking into account the excessive service at the termini and principal stations, the sidings will require as much iron for renewals as an equal length of main line.

The gradients and curves upon this road are light, the maximum gradient 28 ft. per mile, and the sharpest curves of about 1,900 ft. radius, excepting a few short planes and curves upon the branch lines, which are more severe.

The iron rails first laid upon the road were nearly all of British manufacture, of 56 and 57 lbs. per yard, "Erie pattern," with a pear-shaped head, 3½ in. high and 4 in. base; about 50 miles, of similar section, from Brady's Bend, Pa., which proved dangerously brittle, having been the only American rails now known to have been laid in the first track. The British rails were made from piles apparently composed of only one kind of iron, presenting an even, granular fracture throughout the section, and were much better welded than any made in England or in America, which we have since procured to replace them. They were 15, 18 and 21 ft. long—chiefly 18 ft; partly laid with cast iron and partly with wrought iron chairs; the joints opposite, and resting upon a single tie. The sleepers were mostly of white oak, laid 2½ ft. apart centres; 8 ft. long, 6 in. thick, and from 6 to 9 in. wide. The ballast was of sand, or very fine gravel; but the road bed was not thoroughly ballasted—in parts, not at all.

As would be expected from these conditions, the rails were rapidly bruised at the ends; so that as early as 1856 those laid previous to 1852 were in desperate need of repairs, and a force of smiths was in that year set at work mending them; by which means a large proportion of the rails, which had to be removed because of their bruised ends, were restored to the track. The condition of the main line was also helped, by taking the sound railings from the sidings and branches, and

* From a paper read before the Am. Society of Civil Engineers, by Chas. Paine, C. E.; with remarks on the construction and wear of rails, by J. Dution Steele, C. E.

replacing them with battered or mended rails, so that the necessity for the purchase of new rails for repairs was postponed.

Since 1859, the surface of the track has been maintained in excellent condition, and the road has been in as good order, in respect to depth of ballast, drainage, and prompt renewal of sleepers as any of the best lines in the United States; so that rails have had a fair chance to show good results in wear, if the nature of the metal from which they were made and the mode of its manufacture would permit. It would have been better for the track and for the rolling stock, if repairs had begun sooner, and if they had been more liberal in amount, at first; for the tables given here, which show what was done by way of repairs, do not fully indicate what ought to have been done, but only what it was possible to get along with.

A considerable and judicious economy was effected by the mending of rails, instead of re-rolling them, since the cost of re-rolling has averaged, during the period included in this account, about $3,500 per mile, while the cost of repairing rails by hand has averaged about $600 per mile; the mended rail not being so good, of course, as the re-rolled rail, but serving the purpose of keeping the track in a condition of comparative smoothness.

On a part of the main line, 18 miles in length, which had already been re-laid with mended iron, where the grades were very light and few curves, it was found that the mended rails averaged a wear of twenty months before being taken up to be again repaired; on branches, they wore longer.

The metal laid down in renewing the track, except about 30 miles of British iron, has been chiefly re-rolled rails of 61 lbs. weight per yard, with a pear-shaped head; 4 in. high and 4 in. wide on the base. About 50 miles were laid with fished joints, for which the section is of improper shape, and which, of course, did not do well; the remainder was laid with a modification of the "*Howe joint.*" This joint has proved the best of any, upon a light, sandy ballast, the only material which was available upon this line, and one which requires that the joint should have the broadest and steadiest bearing upon it which can be devised. Reports of the condition of all the rails removed from the track, show that where the plate chair upon a single tie is in use, $\frac{64}{100}$ of the whole number are bruised at the ends only; whereas, upon the portions of the line where the Howe joint is laid $\frac{29}{100}$ of the whole are so bruised. Since 1858 the centres of the sleepers have been laid 2 ft. apart; since 1864 the sleepers have been 9 ft. long.

It will be observed in the tables that the rails of 1864 and 1865 proved exceptionally bad. Previous to 1864, the rails had been re-rolled in "two high" rolls, from solid piles of from $6\frac{1}{2}$ to $7\frac{1}{2}$ in. square (sometimes composed entirely of re-worked rails, sometimes with a head-flat of harder metal), into rails 21 ft. long. At this period, the enormous cost of iron, owing to the rebellion and to the tariff, caused railway managers to seek for the cheapest quality which could be obtained; and although re-rolled rails were then evidently inferior to the rails first laid down, and were wearing out with alarming rapidity, resort was had to "three high rolls," and to piles from 9 to 10 in. square, in which were from 3 to 6 pieces of old rails which had not been broken down into flats; and these piles were rolled out into rails 27 ft. long. This mode of manufacture continued until near the close of 1867; by returning then to solid piles—in some reducing them in size, and by the use of raw puddle-bar between the harder head-flat and the re-worked old rails—better welding has been secured, and the resulting wear has been much prolonged; yet these rails are not equal in quality to those made from 1860 to 1863. The length adopted for rails after 1865 was 24 ft. Since this time, it has been found that the larger the proportion of new metal introduced into the piles, the better have been the rails—a result probably due to the fact that a great part of the rails which were being re-rolled, having been re-worked once or twice before, had become quite unfit for making rails again. Although this experience of 1864–5 was convincing that the solid pile is better than one composed in part of old rails, not broken down, yet, as many rail makers and some engineers still maintained a contrary opinion, an experiment was afterwards made to settle the question. A lot, some hundreds of tons, of rails was made from piles in which there were three unworked pieces

of old rails; and another lot was made from the same iron and according to the same specifications, at the same mill with the first lot, with only the difference that all the old rails used were first broken down into flats. These two lots of rails were laid down in situations where they would undergo similar wear, and at the end of one year the two classes were compared; of those made with old rails in the pile, $\frac{1}{7}\frac{1}{2}$ had been removed from the track, and many others were showing signs of disintegration; of the rails made from the solid piles, $\frac{1}{5}\frac{1}{2}$ of the whole had been removed, and the remainder were apparently in good condition.

TABLE No. 1.

NEW AND REPAIRED RAILS LAID DOWN UPON THE WHOLE ROAD.

Year.	Miles of Road Operated.	Miles of New Rails Laid Down.		Miles of Rails Repaired.		Miles of New and Repaired Rails Laid Down.		Average Number of Trains Over each Mile in the Year.
		In Year.	Total.	In Year.	Total.	In Year.	Total.	
1852.	330	....	.....	....	....	....	....	3580
1853.	334	....	.....	....	....	....	....	4180
1854.	340	....	.....	....	....	....	....	4620
1855.	340	....	.....	....	....	....	....	4950
1856.	343	....	.....	30	30	30	30	4670
1857.	567	....	.....	65	95	65	95	3280
1858.	574	...	....	86	181	86	181	2710
1859.	574	6.96	.....	84	265	91	272	2650
1860.	574	8 62	15.58	79	344	88	360	2780
1861.	574	10 18	25.76	80	424	90	450	3100
1862.	574	20 87	46.63	95	519	116	566	3600
1863.	574	23.56	70 19	86	605	110	676	3790
1864.	570	39.05	109 24	97	702	136	812	3840
1865.	575	46.18	155 42	94	796	140	952	3800
1866.	578	91.03	246.45	81	877	172	1124	4130
1867.	583	66.30	312 75	122	999	188	1312	4110
1868.	587	87.33	400.08	138	1137	225	1537	4570
1869.	596	94.85	494.93	73	1210	168	1705	5000

Note.—The length of main track maintained after 1856 was 524 miles; the subtraction of this sum from the numbers in the column of miles operated will give the length of the sidelings.

Jan. 1, 1870.—There remained on the branches 120 miles of the iron laid in 1856-7, all of which had been repaired.

The great increase in miles repaired in 1867 and 1868 is due to the increased length of the rails repaired.

In 1864 the use of a branch, four miles long, was suspended.

TABLE No. 2.

TRAFFIC BORNE BY THE NEW RAILS LAID DOWN UPON THE WHOLE ROAD.

Year Jan. 1 to Dec. 31.	Miles of Rails Laid Down.	Miles of same Rails Remaining in Track Jan. 1, 1870.	Per cent. Remaining.	Per cent. Worn Out.	Average Number of Trains over each Mile in the Year.	Average Number of Trains which have Passed over Rails Remaining Jan. 1, 1870.
1859.	6.96	1.22	17.5	82.5	3300	50,000
1860.	8 62	3.52	40.8	59.2	3480	46,500
1861.	10.18	4 65	45.6	54.4	3880	43,000
1862.	20.87	6.25	29.9	70.1	4500	38,500
1863.	23.56	9.34	39.6	60.4	4740	34,000
1864.	39.05	10 86	27.8	72.2	4800	29,500
1865.	46.18	23.12	50 0	50.0	4800	24,500
1866.	91.03	76.30	83.8	16.2	5160	19,500
1867.	66.30	59.70	90.0	10.0	5140	14,500
1868.	87.33	86.63	99.2	0.8	5710	8,900
1869.	94.85	All	....	....	6100	.....

This Table is calculated upon the assumption that upon one-third of the whole length of the line, where very little new iron has been laid, only one-half the average traffic is experienced This assumption is very nearly correct, and rejecting the service upon this one-third of the line from the calculation of averages, the above results are obtained.

TABLE No. 3.

TRAFFIC BORNE BY THE NEW RAILS LAID DOWN UPON THE WESTERN DIVISION.

Year Jan. 1 to Dec. 31.	Miles of Rails Laid Down.	Miles of same Rails Remaining in Track Jan. 1, 1870.	Per cent. Remaining.	Per cent. Worn Out.	Average Number of Trains over each Mile in the Year.	Average Number of Trains which have Passed Over Rails Remaining Jan 1, 1870.
1859.		None.	..	..	5396	.....
1860.	2.91	0.58	18	82	5350	72,000
1861.	3.17	3.13	39	61	6170	66,000
1862.	8.03	1.57	12	88	7260	59,500
1863.	13.12	4.51	30	70	8020	52,500
1864.	14 78	3.44	13	87	7530	44,500
1865.	26.14	0.62	4	96	7470	37,000
1866.	15.68	9.02	42	58	7910	29,500
1867.	21.46	23.19	80	20	7910	21,500
1868.	28.74	23.32	99	1	8890	13,500
1869.	23.46	28.79	100	..	9000	.....
	28.79					

Upon this division, as upon the whole road, the traffic has been proportioned as follows:

Freight trains	0.5
Passenger trains	0.4
Working trains	0.1
	1.0

The above tables have been compiled from the annual reports and from the records of the Engineer's department. Excepting the first two or three years of the existence of the Railway Company, accurate accounts have been kept of the miles run each year, by the engines, including switching engines. For those years, the miles run by engines have been calculated from the traffic returns; from this account of the total number of miles run by engines has been deduced the average number of trains over each mile of the track, dividing the total miles run by the total number of miles of road operated, including sidings. Upon the western division of the road, which is about 100 miles long, and the most severely worked of any part of the line, the miles run by engines have been recorded separately from the accounts of the other divisions; and as the traffic over this division is very uniform throughout its length, Table No. 3, which shows the experience of 10 years upon it, is a very correct exhibit of the performance of re-rolled rails.

In considering these tables it should be remembered, as indeed Table No. 1 clearly reveals, that the life of all the iron has been prolonged to its farthest limit by repairing; this was more practicable with the first rails laid down than it is with modern ones; because, although from the imperfection of the joint used, they became battered at the ends, they remained sound in the middle, being more thoroughly welded. The rails now made are laid upon an improved joint; if they fail anywhere it reveals bad manufacture, and the imperfect welding generally extends throughout the length of the rail, rendering it useless to repair it—so that only about one-half the number of rails formerly repaired in each year are now mended, although by improved machinery it can be done at less cost, and better.

I am aware that this account of an experience with iron rails will not have the interest which it would have possessed before steel rails were so generally adopted for the renewals upon heavily worked lines; yet, even now, there are engineers who need to be reinforced in their struggle against mistaken views of economy, and to these I offer this contribution, as *Memoires pour servir.*

The length of main track maintained after 1856 was 524 miles, the subtraction of this sum from the numbers in the column of "miles operated" will give the length of the sidings.

REMARKS BY J. DUTTON STEELE, CIVIL ENGINEER, MEMBER OF THE SOCIETY.

Referring to the paper which has just been read on the wear of rails, etc., there is no doubt but it is a correct exposition

of the experience on the road referred to, and as such is of value ; but so various are the influences, both from the modes of manufacture and the local peculiarities to which rails are subjected, that statistics from other roads may be provided showing directly opposite results in several important particulars.

We have, in this paper, the principle strongly implied, if not directly expressed, that iron may become so highly refined by repeated workings, that it cannot be welded without the interposition of less pure layers—a popular theory among rail makers, but one which I apprehend is entirely in error. Indeed, I have heard this mode of making rails characterized as not welding their parts, but sticking them together with cinder. The best iron we have is made from scraps ; we hear nothing of the difficulty of welding them, no matter how often they have been worked ; the more worked the better. The celebrated Damascus blades, the highest quality of carbonized iron of which we have any knowledge, is said to be made of wire ; and the same principle is acknowledged in our country, where wire ropes are much used. When superior iron is needed it is made from worn-out wire ropes ; though more care is required to weld pure than impure iron, particularly where it is worked in large masses. Those who were connected with the early railroad experience in this country have a pleasant recollection of the double refined Eba-Vale rails, which were among our first importations. Unfortunately for the rail interest, when worn out as rails they were too valuable for re-conversion, and found their way into car-axles and other similar uses. The manufacturers of these higher qualities of iron found no difficulty in welding them, though the rail makers would sandwich them with their own poor stuff, if they were allowed to do so.

In a somewhat extended experience upon one of the largest freight roads in this country, it was my practice, for many years, to have the old rails reconverted, without any admixture of new iron ; the best rails, such as the Eba-Vale, were selected for the heads, and the inferior for the flanges ; all were broken down into slabs and thoroughly welded ; and, to secure as perfect a weld as possible, an English mode of effecting the same object was adopted, that of taking upon the rail piles two welding heats, by passing them several times through the rolls, after the first heat, and returning them to the furnace before they were finally drawn into rails. The result was better rails than were obtained by any other mode ; better, even, than new.

I may here refer to what I apprehend to be a prevalent error as to the use of hard granular iron for the heads of rails. The Eba-Vale iron, which produced such satisfactory results, was not of that character ; it was a well-worked fibrous iron, and I believe all the best results have been produced from iron of that character in the heads. Some fifteen years since, an experiment was made under my observation, bearing upon this point : Rails made of fibrous and granular iron were laid alternately upon a heavy-freight-bearing road ; at the end of six months the fibrous heads showed the most marks of wear ; at the end of twelve months the granular heads began to break up, and the result was that the soft, fibrous rails wore out two of the hard granular.

In the early railroad experience a patent was taken out in England for making the heads of rails of granular iron, and at least two patents have since been taken out in this country for the same object ; but all with the same result—all have passed into oblivion, under the test of practice. There are several problems in the wear of rails which may be worthy of note. We all remember what a run the double-headed rail had in England, and how signal has been its failure ; the first head subjected to the action of the wheels became granulated and its tensile strength destroyed, so that when the rails were inverted they broke.

True to the same principle, we find that any cause which changes the position of rails in the tracks, so as to alter the bearing of the wheels upon them, causes their destruction. If they are reversed side for side to the flanges, they wear out quickly, and even if they are taken up from one point in the road and laid down in another, by which means the bearing of the wheels upon them is, of necessity, more or less changed, the granulated surface is broken up, and their durability is decreased.

INDIA-RUBBER TYRES.

From "Engineering."

Everybody has heard — through the medium principally of the non-professional press—of Mr. R. W. Thomson's road steamers with india-rubber tyres and of their wonderful performances. It has been narrated in glowing terms, "many times and oft," how they will run over soft roads and hard roads, rough roads and smooth roads, how, in fact, they appear rather to have a preference for bogs and quicksands, and places where there are usually supposed to be no roads, and how they are capable of being managed with such ease and certainty that the performance by them of Scotch reels and Highland flings are mere trifles, which they might be supposed to undertake as a relief from more arduous duties. All these things have the public been told over and over again—although not these precise words perhaps—and, as a consequence, india-rubber tyres have in unprofessional circles come to be regarded as possessed of qualities little short of miraculous, and there has arisen a demand for engines fitted with them which the original makers, Messrs. T. M. Tennant & Co., of Leith, have been unable to satisfy. Under these circumstances, we find that the manufacture of engines on Mr. Thomson's plans has been commenced by Messrs. Robey, of Lincoln, and Messrs. Ransomes, Sims, and Head, of Ipswich, while Messrs. John Fowler & Co., of Leeds, and Messrs. Aveling & Porter, of Rochester, have also become Mr. Thomson's licensees, and have become builders of engines having india-rubber tyres, but otherwise made according to their ordinary patterns. Now, we have no wish to condemn india-rubber tyres *in toto*, but we think that the time has come when an attempt should be made to set them down at their proper value, and this value we believe to be, commercially, far below that at which they are generally estimated. The chief advantages claimed for the india-rubber tyres are, that they save the engine from shocks and jars, that they give a greater adhesion than would otherwise be attainable, and that they prevent injury from being done to the roads; and that these are advantages well worth attaining we are quite willing to admit. We are also ready to acknowledge that in travelling over paved or other very hard, but uneven, roads the india-rubber tyres do good service, but the question which we consider to be open is, whether this service is commercially worth what it costs. A set of tyres for such an engine as that exhibited by Messrs. Robey, at the Smithfield show, costs about £230 for india-rubber alone, independent of the protecting chains and charges for royalty, and what has yet to be proved is whether this increase in the first cost of an engine is compensated by the subsequent reduction in wear and tear. The only way in which this can be proved is by a comparison of the cost of maintenance of an ordinary traction engine and one with india-rubber tyres doing the same work; and, at present, so far as we are aware, no such comparison is available. The next point is that of adhesion; and here we regret to say, that we must differ materially from the conclusions which have in most instances been drawn from the performances of engines with india-rubber tyres.

When Mr. Thomson first brought his engine before the public, the india-rubber tyres used by him took a direct bearing upon the ground, and there can be no doubt that under many circumstances the elasticity of the india-rubber, when thus used, enabled it to give a "grip" exceeding that obtainable with ordinary iron tyres. Experience showed, however, that the india-rubber needed protection, and this protection Mr. Thomson obtained in a very ingenious way, by surrounding his tyres with a kind of chain armor composed of thin steel plates having their ends bent down on each side of the tyre, and connected by links. In Messrs. Robey's engine at the Agricultural Hall, the plates or shoes just mentioned are 5 in. wide by $\frac{3}{4}$ in. thick, and as they are but about $1\frac{1}{2}$ in. apart it will be seen that the exposed surface of the india-rubber bears but a small proportion of the total bearing surface, and can influence the adhesion to but a proportionally small extent. It is urged, we know, that the elasticity of the india-rubber by increasing the area of the bearing surface increases also the adhesion; but although on roads of a certain class this may be true, yet we

doubt if the results are superior to those which could be obtained by the application to a traction engine of larger or broader wheels of the ordinary kind. So far, we have spoken of this part of the subject on what may be termed by some theoretical g ounds; but we have in our possession practical data which corroborate us in our opinions, and these data we shall probably shortly speak more fully. The last point is the action on the roads, and here we may again express a doubt as to whether india-rubber tyres possess any important advantage over extra large wheels of the ordinary kind. The question whether a traction engine will sink into a road, or pass over it without causing injury, is purely one of bearing surface, and regarding the matter from a utilitarian point of view we consider the thing which has to be proved by the advocates of india-rubber tyres is, not that such tyres can afford this necessary bearing surface, but that they can give it more effectively and at a less cost than it can be procured by other means.

It will be seen that throughout, our objections to india-rubber tyres are based principally upon commercial considerations, and there can, we think, be no doubt that by these considerations alone the use or disuse of such tyres will ultimately be determined. Our objections, in fact, are urged not against *elastic* tyres, but against tyres formed of such an expensive material as india-rubber now is. An ordinary eight-horse traction engine costs, say, from £360 to £380, while an engine rated at the same power, fitted with india-rubber tyres, costs £600, and the thing yet to be proved is, whether india-rubber is the best investment for this extra £220 or £240, or whether it could not be more advantageously spent in securing durability in other ways. So many traction engines with india-rubber tyres have now been built and set to work in various parts of the world, that it can scarcely be long before data are available which will enable us to estimate such tyres at their true commercial value; meanwhile we reiterate our opinion that this value will be found less than now appears to be generally supposed. That there are certain special circumstances that may warrant the employment of india-rubber tyres we admit; but that for general purposes they are worth the money they cost, we cannot at present believe.

NAVAL POWER AS AN ELEMENT OF NATIONAL STRENGTH.

From "The Iron Age."

Certain facts connected with the war now in progress in Europe, which seem to demonstrate the practical inutility of great navies for aggressive purposes in time of war, are now exciting much earnest discussion in Great Britain and other countries, whose naval power has heretofore been considered the chief element of their strength. Half a century ago, navies were the indispensable prerequisites of successful warfare on a large scale, and without them nations were almost powerless for either offensive or defensive military operations; but the fact that during the present war France has been unable to make any practical use of her vast fleet of ironclads and gunboats, forces practical men in Great Britain and elsewhere to admit that navies are fast becoming practically useless. This decrease in the effective power of navies has been brought about merely through a change in the first conditions of a successful practice of the modern art of war. France, for example, is a very strong maritime power, with the second war navy of Europe, and with wealth enough to build or charter as many transports as might be needed. Her navy is well fitted, well manned, well commanded, and to all appearance in perfect order. Even Great Britain had reason to regard the growth of the French war marine with considerable apprehension for the prestige of her own fleet of floating fortresses, and no other nation had a naval armament that could favorably compare with it in any respect. Nothing has occurred to raise any suspicion of its entire efficiency, nor are there any accidental circumstances, such as a want of coal, that have rendered it necessary for it to remain in even temporary inactivity. There is an abundance of coal at hand, or obtainable from New Castle colliers. Both the Government and the people are, and have been since the beginning of the war, very desirous of making the fleet effective, and the German States present a long

and exposed stretch of sea-coast, offering many points of attack upon which a descent could have been made without difficulty. Notwithstanding these favorable conditions, however, the utility of the French fleet in the war has been comparatively small, having in fact been limited to its power of impeding trade, of frightening the peaceful residents of one or two of the more exposed seaport towns, and of inflicting a certain humiliation on the German navy, which makes no pretensions to strength, and has prudently kept out of the way of danger.

These facts, which are too well known to every intelligent observer of the progress of military events in Europe to require extended comment, seem to indicate that, except for purposes of transportation, for which armed vessels are better adapted than transports sailing under convoy, navies have lost a great part of their former importance. The reason of this is easily explained. To make a fleet effective it must be aided by a military force capable of making a descent. Such a descent, to be dangerous, must be made by a force capable of maintaining itself upon the coast after its naval support is withdrawn ; and such a force, to be safe, must comprise a total of men, horses, and field artillery which no existing navy could possibly convey at one time. No navy, except the British, could carry for any long distance more than 40,000 men. It is extremely difficult to transport a complete regiment of 1,000 men in a s eamer of any available size for any voyage, however short ; and when the steamers are of average tonnage and capacity, and artillery, cavalry, munitions, food, quartermasters' stores, and medical appliances have also to be conveyed, it is useless to calculate upon less than three large vessels to every 1,000 men. One hundred and twenty first-class transports make, it must be admitted, a considerable fleet, requiring a large convoy of iron-clads ; yet such a fleet cannot carry in safety more than 40,000 men, and such a force cannot, without incurring risks which no prudent general would care to assume, make a landing upon the shores of an armed nation. The French might have seized Hamburg, for example, and if there were anything to be accomplished by such a demonstration they would, doubtless, have made the attempt ; but they could not have held it, or, holding it, they could not have made an advance that would have materially affected the results of the war. The days are past when an army of 40,000 men constituted a formidable force. Armed nations are in the field, and no force which might be conveyed in one trip by sea could have any appreciable effect upon their colossal strength ; while to make many trips is to leave the first expedition isolated, without communication, and without supplies of food or munitions in case of emergency.

Beside these difficulties in the way of utilizing naval power, however, modern science has contributed its discoveries and inventions, and, by its torpedoes and other hidden engines of destruction, made the mouths of harbors and rivers dangerous cruising ground for hostile fleets, even if composed of the strongest iron-clads. But, even without these defences, an enemy's coast cannot be made a point of attack unless something more than the destruction of life and property is to be accomplished. Modern ideas of warfare do not justify the ruthless bombardment and destruction of unprotected seaport towns, nor do they sanction the needless demolition of fortified cities upon the coast, nor the infliction of more injury upon them than is needed to overcome resistance. It will, therefore, readily be seen how much the aggressive power of modern navies has declined, and should the code of international law abolishing privateering meet with universal acceptance, and the rights of private property at sea be respected by the war vessels of all civilized nations, there will be little left for navies to do but to blockade ports, defend harbors, and serve as transports. These facts, which are forcing themselves upon the notice of intelligent men of all nations, must sooner or later meet with universal acceptance, and national policies must be shaped in accordance with them. Great navies are becoming less and less important each year as elements of national power, and the time is not far distant when a nation possessing a sufficient number of swift light-draught gunboats, adapted to its customs service in time of peace, and suitable for convoys and dispatch-boats in time of war, will consider itself as well off, in point of naval armament, as a nation that boasts a vast fleet of ponderous iron-clads.

IRON AND ITS MANUFACTURE.*

With the almost ceaseless hum of machinery in motion, which has justly been considered one of the great attractions of the Fair, now so successfully drawing to a close, still sounding in our ears, and nearly the whole of it made from iron, cast or beaten, or twisted into forms of use and beauty, it is certainly quite unnecessary to expatiate on the importance of iron, or its constantly recurring and ever-increasing necessity in our daily life. The greater or less use of iron has well been pronounced a fair measure of the degree of the real civilization, and extent and variety of useful industry, which prevail in modern countries, and is perhaps the surest single means of readily judging of any people's position in the family of nations. The manufacture of iron was one of the earliest industries requiring joint or associated action, or the labor of several individuals to produce one specific end, the reduction of iron ores having begun very early, and being too difficult for one man to accomplish, to any extent, unaided; and its production quickly necessitates a more or less crude commerce, for nowhere does a family or tribe make its own iron without also producing a certain surplus to be bartered off to the less fortunate or less skilful; and this manufacture and barter, begun almost as soon as men ceased to live entirely by the chase, has continued constantly supporting or stimulating manufactures and commerce, until they have attained the stupendous development of our own day, when every sea is blackened by the smoke of engines of iron steamers, and the wild beast is startled on every prairie and in every jungle by the shriek of the iron horse running on the iron rail.

For what uses iron has already become a universal convenience or necessity we all know, and the catalogue is too long to be even run through in a single afternoon; but after the wonderful strides of the past half century in the manufacture and consumption of this the really precious metal, what man so bold as to attempt a successful prophecy of its future utility; while it is almost as difficult to trace its early real history, stretching back into the dim twilight of man's existence, when shadows and realities are inextricably mingled. That Tubal Cain was one of the earliest workers in iron, is of course a familiar fact to every one who has read an article or heard a lecture upon iron, and its tolerably frequent use seems to have been familiar to many of the Bible writers. Og, King of Bashan, had an iron bedstead; chariots of iron, harrows, and other tools of iron, are spoken of, and a pen of iron conveyed a sufficiently familiar idea to make it a convenient figure for the prophet Jeremiah; while the Israelites were early promised, as specially desirable, a land whose stones are iron. In Homer, both iron and steel are mentioned, and, in the 23d book of the Iliad, a mass of iron, only so large as a strong man might throw to some distance, is offered as a valuable prize at the funeral games of Patroclus. In the words of Bryant's spirited translation,

> "Again Pelides placed before the host
> A mass of iron, shapeless from the forge,
> Which once the strong Eetion used to hurl,
> But swift Achilles, when he took his life,
> Brought it, with other booty, in his ships
> To Troas. Rising, he addressed the Greeks:
> 'Stand forth, whoever will contend for this,
> And if broad fields, and rich, be his, this mass
> Will last him many years. The man who tends
> His flocks, or guides his plow, need not be sent
> To town for iron, he will have it here.'"

At Babylon the huge stones of the bridges were held together by bands of iron, fixed in place by molten lead. Later, Thucydides tells us that the walls of Pireus were fastened in the same way. The Ninevites made tools of iron; and small objects of art made of iron, or iron and bronze, were found by Layard in tombs of early date. And through all the nations of high antiquity, iron is mentioned almost always in a way that shows it to have been a partially common, but always highly esteemed metal. Indeed, from the difficulty of working it with the primitive means at the command of men just emerged from barbarism, it was constantly held at a high price. Iron was exchanged for brass, weight for weight, and, whatever the age of the world, we find substantially the same fact at the same stage of a nation's develop-

* An address by A. W. Humphreys, Esq., Treasurer of the Sterling Iron and Railway Company, before the American Institute, New York, November 1, 1870.

ment; only 150 years ago, Botachoff, in Russia, having bartered iron for an equal weight of copper coin. So, also, in the older ages, as now, those best skilled in the production and manipulations of iron held a certain pre-eminence, and, in some instances, almost the only claim some of the smaller peoples have to a mention in the page of the historian, or which prolongs to our day that slight recollection, or indirect mention, which is their share of fame, has no title but their ability to wrest this metal from the tenacious grasp of combined impurities, and thus make it useful to themselves, and to their neighbors a coveted implement or dreadful weapon.

Thus the Chalybes, a once powerful Arminian race, famous formerly for the quality of their iron, continue to celebrate their superior production and perpetuate their own memory by furnishing us the root of the word chalybeate. They, as other early iron-workers, left slight record of their processes or operations; Aristotle, indeed, mentions that their arenaceous ores were washed, and he also partially describes the operation of making wootz in India; and Diodorus Siculus says that in the Island of Ethalia the ores were roasted, broken fine, perhaps partially reduced to blooms, and sold for iron-making; but these and other scanty particulars contain but little of instruction or warning for us. So of the slight knowledge we possess of the manufacture and treatment of iron in Ancient India, China, and Egypt, where there is plenty of evidence of its early use and importance, but only meagre information as to the methods of obtaining it from the ores, and only deserve notice as showing how soon this metal began its influence and proved its importance. We are only sure that it was *wrought* iron that was produced and employed, and not *cast* iron, which is a comparatively recent production, and it is probable it was all obtained by a primitive direct process, from rich and easily reducible ores.

Down to the time of the Romans iron was too scarce and high to be of general use, but they employed it with comparative freedom; and perhaps, in the absence of files of any scientific press, which now quickly promulgates any new discovery, and the progress made in the adoption of new materials, or fresh applications of old ones, nothing shows more succinctly the change which had taken place in the increased use of iron under that powerful race, than the fact that Homer speaks of death as a sleep of brass, while Virgil, with the same idea in his mind, conveys it familiarly to his public by calling it a sleep of iron. The Romans introduced the manufacture of iron to the Iberian Peninsula, and Spain for a long time furnished not only metal to her neighbors, but also skilled workmen to those who wished to enter upon its manufacture for themselves; and probably France is indebted to Spain for what early knowledge of iron working she possessed, while through France the practice passed on to Germany, and settling among the Hartz Mountains, its numerous forge-fires helped furnish that extraordinary stock of goblin stories and fairy tales which were the delight and terror of our childhood. Further East and North, in Russia and Sweden, a knowledge of iron metallurgy probably came to them through the Scythians in a rude way from still farther East, where the hordes of Indiamen had long made the celebrated wootz, a steel of high quality, though made in the most primitive way, or perhaps from China, where iron and its magnetic properties have been known for ages. But at a later date all knowledge of the art of this manufactnre as now practised, came mainly from England, and therefore it is to her progress that we turn for the proper history of iron and its improved manufacture, as we know it. In Britain, it is extremely probable, but not certain, that the use of iron was known long before the invasion of Cæsar, though we are entirely ignorant of what may have been the method of its manufacture. With the occupation of the southern end of the island by the Romans came quite extensive workings of the rich ores near the sea, and subsequently the Danes carried on the reduction of the same deposits of ores so largely, that at a still later date the piles of cinders left by them supplied many blast furnaces for a long time, with material for the production of pig iron, the more perfect operation of the blast furnace extracting iron from what was worthless slag to the crude operations of Romans and Danes.

The method employed by all the early workers of iron of whose operations we

know anything, was similar to that still in use in India, in Borneo, in Madagascar, and in Africa, and consisted in heating as hot as a natural draft of air, or that artificially supplied by the crudest of bellows, would permit, rich ores of iron in contact with incandescent charcoal, and hammering the viscid mass until the earthy impurities were expelled and an irregular shaped lump of nearly pure iron remained—the "mass of iron, shapeless from the forge," of Homer, and which—still produced, by slight modifications of the same process, in numerous localities throughout the known world—we call a bloom of iron, from the old Saxon word *Bloma*, the *Bloma Ferri* of the Doomsday Book—and which is hamme ed into bars or tools as wanted. This early manner of producing iron continued, with slight change, the universal method until the discovery of cast iron, and, together with its various modifications and offshoots, patented and unpatented, are all different branches of what is known as the direct process of making iron, being a production of malleable iron directly from the ore, at one process, in distinction to the now more common manner, called the indirect method, which first smelts the iron ore by means of the blast-furnace, and then eliminates from the resultant pig iron its carbon and other impurities, by puddling or other means, until malleable or wrought iron is obtained. That this indirect and roundabout way should be now generally adopted, seems almost paradoxical, and an inventor of one of the improved direct processes, for such inventors are numerous, being led by an *Ignis Fatuus* to attempt the short cut across, instead of making the best of the road around, asks, very pertinently, why convertiron already malleable (in the ore) into cast iron, to be reconverted, at much labor and cost, into malleable iron again? The question is an obvious one, and the only answer is, that thus far the indirect process has proved the most useful for the reduction of the majority of workable ores, in large quantity, all direct processes hitherto employed being applicable only to rich, selected, and easily reducible ores, wasteful of fuel, prodigal of labor, or irregular in their result. It is undoubtedly the dream of every iron-smelter who thinks much, or dreams at all, to find some method of obviating the use of the blast-furnace, but no commercially successful way has yet been found of realizing this dream on a large scale—that is still one of the not improbable achievements of the future.

The terms *wrought iron* and *cast iron* may occasionally lead to confusion and misunderstanding, and it should be constantly borne in mind that iron is iron, however and from whatever ores obtained. Wrought or malleable is nearly pure iron, and is malleable and ductile, while cast iron, as well as pig iron, which is only a form of cast iron, is a compound of iron and carbon, with some other impurities usually existing previously in the ore in too large or too intimately combined quantity to have been entirely removed by the action of the blast furnace, and is neither malleable nor ductile. Malleable castings, of which keys, the iron-work about a horse's harness, and many small articles are made, is cast iron in which carbon was originally almost the only impurity, and which, by a process of cementation, has been so nearly removed as to make the castings slightly malleable, though destitute of fibre, which is developed in wrought iron, but not at all ductile.

To properly trace the history of the present iron manufacture we have only to go back about 500 years, to the development of the process of making pig iron, by the blast furnace, at a date which cannot be fixed with precision, but about the beginning of the 15th century. It is probable that the gradually increased height of the little furnaces or forges, formerly in use, with the greater intensity of blast, also gradually increased, finally led to the complete melting of the ore, and so, by the final addition of some earthy flux, cast iron was obtained; but where and by whom the change was turned to any practical account is unknown, though the first furnaces erected to make only pig iron seem to have been in France, or what is again, unfortunately, the debatable land between France and Germany; and one of the earliest English makers of pig iron imported a workman from France to teach him the art. But if France can claim the origin of the manufacture, England soon took and has since maintained the front rank in the quantity made, though to Sweden we still look for a superior quality of many descriptions of

iron. The quantity of iron made in England was for a time seriously checked by want of fuel. Down to the beginning of the 18th century, charcoal had been the only fuel employed to any extent in the manufacture of iron, and the immense forests of Russia gave her, for a time after the manufacture was established there, a certain advantage, and she sent large quanties of iron to England, where the drain of timber for iron making had been so great, that in 1851 stringent laws were passed to prevent the consumption of timber in any new iron works within 22 miles of London, or 14 miles of the Thames, such legislation being necessary to prevent a famine of fuel, the whole kingdom being then dependent on wood; this and some additional legislation having failed of its object, it was finally forbiden to use any timber for charcoal for making iron.

Some fuel was necessary, and the Dudleys spent much time and money in their experiments in the use of pit coal, finally succeeding in making iron by its use, but, through various obstacles, many of them thrown in the way by jealous charcoal iron-makers, not being able to establish it as a regularly accepted article.

For nearly 80 years after the final abandonment by Dudley of his persevering trials and partial successes, nothing was accomplished toward the practical solution of the problem, until, finally, in 1735, Abraham Darby, of Colebrookdale, succeeded where so many others had failed, and the manufacture began a fresh period of prosperity, though still only partial, for the introduction of mineral coal necessitated further improvements which the state of the mechanical arts made still impracticable, and England continued partially dependent on Sweden and Russia. In 1760, Smeaton erected, at the Carron Works, the first large blowing cylinders, and these, furnishing the larger quantity of air necessary with pit coal, or rather the coke from pit coal—raw coal being yet unused—showed iron-masters in what direction lay the chief difficulty hitherto preventing the complete success which had been expected to follow Darby's discovery, while, at about the same time that Smeaton was constructing his large cylinders, Watt was improving the steam engine, and he had so far perfected it, with the aid of Boulton, that in 1788 iron-masters were beginning generally to employ his double engine, which supplied the power necessary to work the large blowing cylinders, thus completing what Darby had begun; but it extended no further than the blast furnace and the manufacture of pig metal. Another step had been needed for the speedy and economical conversion of pigs into bars; this was supplied theoretically by a patent issued to Peter Onions, in 1783, in which the *rationale* of the puddling process was described, and the principles involved fully covered. The next year Henry Cort, of Gosport, took out a patent covering the practical use of the puddling process, and the use of grooved rolls, and to Cort is generally ascribed the merit of both inventions; and he has been styled the Father of the Iron Trade; although, as a matter of fact, the mode of puddling described by neither Onions nor Cort is precisely followed at the present time. Cort spent a large sum in perfecting and introducing his inventions, and had what seemed the shrewdness to get a Government official interested in his patent, and to furnish a part of the capital necessary, and Onions sank out of sight. Cort's Government friend was caught, however, in a defalcation or "irregularity," having, in fact, stolen the money he advanced to Cort. The Government seized the patent; it was locked up in court, and Cort finally died a poor man, ruined by what has proved to be the means of wealth in England.

These improvements laid the foundation of England's supremacy as an iron producer; they speedily came into general use, and the production of iron, aided by the fostering care of the Government and the unusually high price of foreign iron, rapidly increased. As the completion of these improvements, about 1790, was the commencement of the present era of iron making in England, it may be worth while to consider, for a moment, her previous and subsequent position in this industry, from a commercial point of view. The quantity of iron made in the Kingdom nearly sufficed for the consumption of Great Britain, until the passage of the stringent Fuel laws above spoken of, and there were neither imports nor exports of any great quantity, until the seventeenth century. Statistics of the whole product of the British Islands previous to 1715 are not to be had; in that year there were

estimated to be about 300 furnaces in operation, and the price of pig iron was about £6 per ton; from the dearness of fuel and the operation of the laws against the employment of charcoal at iron works, the production gradually fell off, until in 1740 there were only 59 furnaces in operation, producing 17,350 tons per annum of pig iron, while the net imports of iron of all descriptions, mainly from Russia, Sweden, and the American colonies, were about 20,000 tons. Then came Darby's success with pit coal, and the make immediatly began to increase, and continued to do so moderately, until, in 1788, the total production of Great Britain was 68,300 tons, and her net imports only about 15,000 tons. Then came Smeaton, and Watt, and Cort; the duty on bars was put at 56s. per ton, the value of bar iron being about £18 per ton, and the manufacture fairly began the prosperity it has ever since retained, with occasionally a dull period of short duration. In 1796, an additional duty of £1 per ton was laid upon bars, a rise of about 30 per cent. took place in Russia, and, to quote Tooke, "the produce of iron proceeded so rapidly, that, with the aid of further duties, amounting almost to a prohibition of importation, it not only kept pace with the increasing demand, but actually nearly superseded the use of foreign iron in this country, and furnished a surplus for exportation." In 1797 the production was 125,000 tons. So strong had been the stimulus that, in 1801, there were building, or in blast, 47 new furnaces, 125 being then the total number of the old ones. Let it be borne in mind that no new process had been discovered since 1790, nor had any special improvements been made, meantime, in furnace machinery; the increase was due entirely to the increased demand, to a rise in foreign iron caused mainly by this increased demand, and by the action of the Government in so arranging the duties that Great Britain might herself reap the full benefit of the changed circumstances, carefully sustaining the feeble steps of this branch of industry while thus in its infancy. In 1806, the total number of furnaces in Great Britain was 173, making 258,000 tons per annum, an average of less than 1,500 tons to each furnace. In 1825 there were 364 furnaces, of which 261 were in blast, making 581,000 tons per annum. The duty at this time on bar iron was £6 10s. per ton, having been gradually raised to this figure since 1796, and Great Britain, from being an importer, had so changed her relative position in the iron world, that her net exports were 90,000 tons.

There was still no further change in modes of manufacture, but in 1828, Mr. J. B. Neilson, of Glasgow, took out his patent for the use of heated air, instead of the cold blast, which had alone, until then, been used to support internal combustion in the blast furnace. Whatever merit we may gladly concede to the predecessors of Mr. Neilson for their improvements, it is certain that no single invention in the manufacture of pig-iron has been followed by so great benefits or occasioned so marked advance as the use of the hot blast; although it deserves to be called a discovery rather than an invention, for, in the words of Dr. Percy, "there is no reason to believe that the patentee had, at first, any adequate conception of the value of his invention, and the great influence it was destined to exert upon the smelting of iron." But the iron-masters were not slow to perceive the great advantages it offered, and promptly availed themselves of them, so that by 1835 it is said that the heated blast was in use at every furnace in the kingdom, with a single exception, and the quantity of coal necessary to smelt a ton of iron was reduced, in 3 years, from 1-20 tons, coked, to $2\frac{1}{4}$ tons, used raw, actually consumed in the furnace, and 8 cwt. required to heat the blast, or a total of 2 tons 13 cwt. of raw coal, the Calder Works having demonstrated, in 1831, the needleseness of coking when hot blast was employed, while later the expense of any extra fuel for heating the blast was dispensed with, the waste gases from the top of the furnace being used for that purpose. This latter improvement originated in France, where, in 1811, M. Aubutot took out a patent for their employment and utilization, reserving to himself, however, only their use as far as connected with his own business, the cementation of steel—giving to iron-masters, with singular generosity, not only all the benefits they could derive in other ways from his patent, but carefully instructing such as chose to apply to him in the best way he knew of collecting the gas, although

he foresaw at least a part of the enormous advantages which would finally result from his idea. But little was actually done with the waste gases, however, to assist in smelting, until, in 1854, Mr. Budd took ont a patent in England for the utilization of the gases for heating the blast, and soon applied his principle, not only to the stoves, but to the generation of steam in the boilers, at his furnaces, and since that time it is almost the universal practice to use only the heat from the combustion of these gases for those purposes, and at some furnaces their employment is carried still further, and ore is calcined by them in kilns especially adapted for that purpose ; though whether there is as yet any real economy in this, at large furnaces, remains, to a certain extent, an open question. The people of the United States have especial reason to hold Mr. Neilson in grateful remembrance, for, without hot blast it would be almost absolutely impossible to smelt iron with anthracite coal, the experiment of doing so with cold blast having been thoroughly and carefully but unsuccessfully tried in the United States, in France, and in Great Britain, the earliest recorded trials having been made as early as 1820, near Mauch Chunk, Pa., and next in France in 1827 ; but it was only when aided by hot blast, that Mr. Crane, in Wales, with ovens built by Mr. Neilson himself, finally achieved success with this king of fuels, in 1837, though Geissenheimer had in 1833 taken out a patent in the United States for the use of anthracite, but with no practical results. Again, at Mauch Chunk, in August, 1838, this time with hot blast, and, it is asserted, without a knowledge of Mr. Crane's success, an attempt was made to employ the Pennsylvania anthracites, and a blast of five weeks is claimed to have been perfectly successful, the furnace being owned by Bauman, Guiteau & High. They stopped, from want of ore, in January, 1839, and after somewhat enlarging the furnace, again blew in at the end of the following July, and continued in blast till November of the same year, having produced about 2 tons of iron per day, when working best, with a blast heated to about 400 deg. The size of the furnace was $5\frac{1}{2}$ ft. bosh by $21\frac{1}{2}$ ft. high. The quantity of coal consumed per ton of iron made, I am unable to state.

The Pioneer furnace, at Pottsville, was the next furnace successfully employing anthracite coal, and the same site is still occupied by an anthracite furnace owned by Messrs. Atkins Bros., though the old stack was torn down in 1853, and a larger furnace built on the same foundations. It was blown in by Benjamin Perry, with some general assistance from David Thomas, in July, 1839, and completed its first blast in January, 1840.

The above statements regarding the first use of anthracite seem to me well authenticated by documents written by the parties interested, at, and immediately after, the dates mentioned above, and I believe may be relied on, though there has been some controversy upon whose brow should rest the *corona muralis* of success in this peaceful struggle, and I have taken corresponding pains to determine the conflicting claims.

In a general way, it is sufficient to say that from 1839 dates the employment of anthracite coal for smelting iron in the United States, and the production of this description of iron has, with various ebb and flow, finally reached the handsome quantity of 971,000 tons made in 1869. The primal development of the use of anthracite we must concede to Mr. Crane, in Wales, but the American iron-masters long ago left their Welsh competitors far behind in the production of this particular description of pig-iron, whether there be considered the quantity made, the size and general completeness of the furnaces, or the quality of metal produced, the generally poor character of the Welsh coal, and its excessive decrepitation upon the application of heat, having been powerful hindrances to the growth, at the place of its birth, of this particular branch of iron industry, Wales having made, in 1869, but 28,000 tons of anthracite pig iron. With hot blast and the use of anthracite begins the real history of the extensive manufacture of iron in America. But this sketch would be quite incomplete and unsatisfactory without an attempt to follow, as accurately as possible, the progress of the early iron-workers on this continent, though the record is very imperfect, our forefathers having had quite enough to do to maintain their individual footing without giving themselves much anxiety about general statistics ; and whoever traces carefully the fluctuating fortunes of the

predecessors of the present iron-masters of this country will find that the soldier patriots of Valley Forge were not the only men whose faithful picket-duty in the cause of American independence was attended with immense personal sacrifice and heroic self-denial.

The Red Indian knew nothing of iron extracted from the ore, but sometimes fashioned weapons out of ore as from any tough rock. The first known iron works in America were erected near Jamestown in Virginia, in 1615 or 1619, but after an unprofitable existence of only 3 years, the furnace was demolished by the Indians, and all the inhabitants of the surrounding village murdered, thus ending that initiatory enterprise. We hear no more of any very strong efforts toward the production of iron until, in 1644, forges were established at Lynn and Braintree in Massachuseets, and though only moderately successful, maintained their footing, and iron and its manufactures have never since ceased to form an important proportion of New England industry, nor to foster inventive skill, Joseph Jenks having, as early as 1655, by changing the shape of the common scythe from the old English form, short, clumsy, and ineffective, into the tool we are familiar with, commenced the development of that wonderful aptitude for improving the common utensils of life which we call Yankee genius, and of which the results are now found wherever the steel-trap has replaced the pitfall, the bow and arrow retired before the rifle, or the compact and economical cast iron stove driven out the cold porcelain stove of the Germans, or the warm, but wasteful open fire of the English.

The small ponds in Eastern Massachusetts and of Rhode Island for more than a century supplied an unknown number of furnaces and forges with bog ore, which, by the aid of charcoal from the then dense forests, was smelted into pigs or forged into blooms, and, during this century, the manufacture of iron had been successfully established in most of the Colonies, from Massachusetts to Carolina, but no records worthy of credit now exist to state the definite extent of the total product. The exports of iron, beginning in 1717 with 3 tons, gradually increased until 1750, when 2,930 tons were exported. In that year the British Parliament removed the import duty on pig iron made in the Colonies, and on bar iron if brought to London, but forbade the erection or maintenance of any mill for rolling or slitting iron, or any plating forge, the object being to get a new source of supply for raw irons at a time when the home-make had become insufficient to supply the demand, and at the same time prevent the Colonies from producing iron further advanced than the pig, lest England should lose anything of her own importance as a manufacturing centre. In 1756, a new law opened the other ports of Great Britain to Colonial bar iron, and American exportation rapidly increased, though in a small way, the total in 1760 being 2,700 tons; in 1755, 4,342 tons, and in 1771, when it reached its maximum, 7,525 tons. The importations, meantime, had been small quantities of Russian and Swedish iron, say from 100 to 500 tons per year. Further than these scanty records of exports and imports, there exists no authentic information of the condition of the Colonies, as a whole, prior to the Revolution. With the outbreak of the war, exports naturally ceased, and the demand for war material not only taxed existing mills to the utmost, but caused a rapid extension of the industry, which was suddenly checked, and many individuals ruined, by the large quantities of foreign iron brought in as soon as the close of the war again opened our ports, England having in the mean time largely increased her manufacturing facilities.

The industry remained extremely depressed until the passage of the first Tariff bill in 1789, the rates in which were raised in 1792, again in 1794, and the quantity of iron made steadily increased. In 1810 the United States contained 153 furnaces, making 53,908 tons of iron. From the lack of any compulsory returns of manufacture to the Government, year by year, and the want, only recently supplied, of any association among iron-masters, through which, for mutual advantage, such information could be obtained, there are but imperfect records of the quantities of pig iron made in the United States. I will give all the figures for which any degree of correctness can be claimed down to 1850.

In 1810 we made..... 54,000 tons.
In 1828 we made.....130,000 tons.
In 1829 we made.....142,000 tons.
In 1830 we made.....165,000 tons.
In 1831 we made.....191,000 tons.
In 1832 we made.....200,000 tons.
In 1840 we made.....347,000 tons.
In 1842 we made..... 215,000 tons.
In 1845 we made.....488,000 tons.
In 1846 we made.....765,000 tons.
In 1847 we made.....800,000 tons.
In 1850 we made.....564,000 tons.

In 1854 there were made 716,000 tons, and from then until the breaking out of the Rebellion the yearly make was from 700,000 to 900,000 tons, varying slightly, increasing and decreasing year by year.

In 1863 the make was..... 947,000 tons.
In 1864 the make was.....1,135,000 tons.
In 1865 the make was..... 931,582 tons.
In 1866 the make was.....1,350,000 tons.
In 1867 the make was.....1,461,000 tons.
In 1868 the make was.....1,603,000 tons.
In 1869 the make was.....1,916,000 tons.

England, during these years, had of course largely increased her production. In 1818 she made 300,000 tons, and gradually augmented this quantity, until in 1835 it first reached 1,000,000 tons.

In 1840. .....1,500,000 tons.
In 1847.....2,000,000 tons.
In 1850.....2,500,000 tons.
In 1854.....3,000,000 tons.
In 1856.....3,500,000 tons.
In 1862.....4,000,000 tons.
In 1863.....4,500,000 tons.

And since then it has fluctuatingly increased to 4,900,000 tons in 1868, and about 5,400,000 tons in 1869.

For the sake of following the history of the commercial progress of our own manufacture of iron, I left the consideration of gradually evolved metallurgical improvements at the introduction of the hot blast and anthracite, from 1830 to 1840. We have seen that a century was occupied in making the five great steps which brought the metallurgy of iron from the comparatively primitive state in which Darby found it, to the threshold of its development in America—namely, the use of mineral coal, of the steam engine, puddling and rolling, hot blast, and the use of anthracite.

The improvements since have been marked in their results, but there has been no one, in the manufacture of pig metal, which has given the trade any single great impetus, and of the several, more or less famous, which have facilitated the making of wrought iron, of steel, of semi-steel, of homogeneous iron, and their various compounds and shades of difference, I have not time to speak—nothing less than a full afternoon could do them a moiety of justice.

In order to appreciate what has been done since 1840, let us glance at the then condition of the iron-making process: The ore was charged, with its accompanying fuel, into the open tunnel-head of furnaces of about 12 ft. bosh and about 45 ft. high; combustion of the fuel and reduction of the ore was effected by means of a blast of say 500 deg., at a pressure of about 3 lbs.; a part only of the waste gases were at all utilized by being taken from some distance below the top of the stack, before they had become really "waste," frequently deranging the proper working of the furnace, while the portion thus taken was of but very little use, by reason of its insufficient mixture with atmospheric air and subsequent only partial combustion; the result was a consumption of $1\frac{1}{2}$ to $2\frac{1}{2}$ tons of fuel per ton of iron produced, the quality of the metal made was decidedly variable, and the production per week about 70 tons. The pig iron was then puddled entirely by hand to make wrought iron, and the purified product rolled into merchant bars, not a rail having then been rolled in the United States. Steel was only made by the old-fashioned processes, either slowly and at great cost, or, if more quickly, of variable and inferior quality. The lines of demarcation between the only three forms of iron then recognized, cast iron, wrought iron, and steel, were strongly pronounced and definite.

It would be unfair not to mention the first use of the raw bituminous coal west of the Alleghanies, as the production of iron with this fuel will ultimately quite surpass in quantity that made with anthracite. David Himrod is said to have been the first to employ it, uncoked, in 1845, being driven by a strike of his workmen to either attempt this or blow out his furnace. He tried the raw coal, and with complete success, thereby opening the door to the manufacture, in 1869, of 550,000 tons of iron made with bituminous coal.

Since 1840, the blast has been gradually made hotter and hotter, and the means of economically and regularly giving the air a temperature of 1,000 or more degrees, have naturally attracted much attention, resulting in the patenting

of various stoves, of which Player's and Cowper's plans may be considered leading methods of accomplishing this end—Player's operating by burning the gas from the furnace in a separate combustion chamber below the pipes through which the cold air passes to be heated, and allowing only the heat to come in contact with these pipes, instead of permitting combustion to take place in the oven inclosing the pipes, as was the old plan, and the results have been very favorable, though it is fair to state that part of the gain from the use of Player's oven arises from the increased number and somewhat changed shape of the pipes themselves.

Cowper's patent, said to be a revival of an old Scotch idea, is but little known, practically, in this country, though favorably used in England, and is founded on the Siemens' regenerative principle, a cellular mass of brick-work being first raised to a high heat, and this heat then imparted to the blast which is made to pass through it, while a similar mass of brick-work is being heated, ready for use as soon as the first shall have become partially cooled. Whitwell's ovens, acting on the same principle, avoid some of the objections raised against Cowper's stove, the principal one being that it clogs readily with dust and is expensive to clean. This Whitwell obviates by making his brick-work into largish compartments instead of cellular. It is claimed that the blast can be heated to 1800 deg. by this stove, and a regular working heat of 1,400 deg. be steadily maintained. To estimate properly the great importance of improved devices for heating the blast, it should be constantly remembered that for every ton of material charged in at the tunnel-head, at least three tons weight of air is blown in at the bottom through the tuyeres; and it requires but little further consideration to impress on any one the great difference that must be exerted on the work of the furnace if this air is put into the furnace already heated, or is introduced cold, and the work of heating, it thrown upon the fuel in the furnaces which should find abundant employment in smelting the ore only. There is also an unexplained advantage in the use of heated blast, it being a fact that, if the air supplied to a common laboratory blow-pipe be heated to say 500 deg., many substances previously infusible by the common blow-pipe frame are readily melted. Why, is yet unknown.

The complete closing of the tops of furnaces is another great improvement with most ores; and, as a rule, whenever a flame is visible at the tunnel-head, we may be sure that a large waste is taking place. The best device yet arranged is what is known as the bell and hopper, or cup and cone, which consists of an inverted truncated hollow cone of cast iron, the cup or hopper filling the throat closely at the top, but considerably smaller at the lower end than at the throat. In this is suspended a cast iron cone by a chain attached to its apex, and so arranged as to be raised or lowered at pleasure; its largest circumference being larger than the downward end of the cup, closes the top of the furnace completely when raised against the cup, and, when lowered, leaves an opening of several inches all around it. Through this the furnace is charged, and as each charge passes through it is immediately closed by raising the cone, and kept shut until time to admit another charge. The furnace gases, prevented by the tightly-closed cup from passing out of the furnace top, and collected in the open space around its lower end, pass out to the hot-blast ovens, boilers, and roasting-kilns, through proper flues. The principal object of the closed top is that all the gases may be secured for use; but it has other incidental advantages, the cone distributing the raw materials much more evenly than practicable with simply a large hole in which to dump them, while the ability to close or open the throat assists in the general control of furnace action. An excellent English authority says that 600,000 tons of coal are saved in their Cleveland district alone, per annum, by the use of closed tops.

Passing at once from the top to the bottom of the furnace, we find an attempted improvement, not yet generally introduced, in Lurman's closed hearth. This plan builds up the hearth in a complete circle, leaving only a small hole at the bottom for the iron to run out, and, where the cinder notch usually is, a tuyere one and one-half inches in diameter, is inserted, through which the slag runs off as fast as formed. The advantages claimed, and, in some places where this

hearth is introduced, fully realized, are a hotter hearth, there being no heat wasted to keep up the temperature in the useless channel between the hearth and the dam; while the tuyeres, instead of blowing into the cinder, as is frequently the case, are inserted at a level of about nine inches about the slag outlet, so that the materials to be smelted have the full and uninterrupted effect of the blast; less time is required for casting, while the hearth is kept so hot as to have no tendency to "grow up," and, there being no fore hearth, there is no crust to break up, thus saving much time; and, as the hearth has no opening through which the materials can blow out, a much higher pressure of blast may be maintained.

Quite in the region of theory, as yet, is the plan of Herr Schintz, of Strasbourg, a metallurgist who has made the action of blast furnaces a special study, and who has suggested innovations which have a plausible appearance of success. It is of course known that of all the atmospheric air blown into the furnace, whether hot or cold, a large proportion consists of nitrogen, which assists not at all in the combustion of fuel, and is of very doubtful utility in any way in the furnace, while it is certainly harmful in diluting the useful gases, and occupies a deal of space that could be much better employed, to say nothing of the fuel necessary for heating the nitrogen along with the oxygen in common air. Herr Schintz's theory has for its object the elimination of part of the great surplus of nitrogen, by working the furnace partially with solid fuel, in the ordinary way, and partly with carbonic oxide, manufactured in separate generators, and forced into the furnace through separate tuyeres, with the ordinary blast. It is applicable, as far as developed, only to hot blast furnaces, and the details are too long to find a place in this paper, but the plan is worthy the intelligent consideration of iron-masters, being theoretically correctly founded.

The size and shape of the furnace have gradually undergone great changes, the whole interior being originally square in horizontal section, and the hearth was made square, or a parallelogram, long after the upper portion of the furnace became circular. When the interior was square, the exterior was naturally so, and was generally formed of stone masonry heavy and massive, but the heavy masonry seems to have no special advantages beyond making a picturesque ruin when abandoned, and the later furnaces, in England and our own Western States, are of what is called the cupola style, the heavy masses of stone at the corners having given place to simple iron columns, supporting a large iron ring, on which is built the stack, the exterior of the fire-brick which forms the hearth being open all around, and the stack itself consisting of the fire-brick lining, with a course or two of red brick external to it, and surrounded by boiler plate securely riveted together, the whole looking not unlike a brewer's huge vat, standing on four legs. The vertical section of the interior varies with the fuel and ores to be employed, and somewhat also according to local fashion; the precise shape, in any locality, is best attained by careful observation of the furnace when blown out. The constant tendency of the best English practice has been to enlarge the hearth, and with beneficial results, though on the continent of Europe, generally, the small hearths are still adhered to. The throat has also been much enlarged from the size common thirty years ago, and the proportionate height of the furnace also increased, where the fuel is strong enough to bear it without danger of being crushed by the increased weight of the larger mass of ore, or the pieces of the crude materials so fine as to obstruct the blast, both which changes have unquestionably increased the economy of fuel.

Now, then, after a lapse of thirty years—since 1840—a combination of the various changes and improvements gives furnaces of 27 feet bosh and 105 feet high; a blast heated at will to 1,400 deg., blown with a pressure of from 5 to 7 pounds per square inch, into the upper portion of a roomy, circular hearth, tightly closed, except the absolutely necessary apertures to permit the egress of scoriæ and metal, and after supporting combustion, which must produce a heat of at least 3,000 deg., and mingling with and partially forming the gases evolved, reaches the tunnel-head at a temperature of about 500 deg., and there, finding the throat entirely closed, is compelled to seek its exit through side flues, and do still further service—after being mixed with atmospheric air—in heating a fresh supply of

air, or generating steam to force it, in its turn, through the same route; the result being the production at a single furnace, of 700 tons per week, or from one stack, in 1870, more than double the quantity all Great Britain made in 1740, and made by the use of less than a ton of fuel per ton of iron.

The total quantity of pig iron made in the United States in 1869 had a greater value, in this crude state, at average prices, than all the gold and silver produced in our country, by some $5,000,000. Throughout Europe, the advance in iron metallurgy has been scarcely less marked than here and in England.

	Tons.
In 1845, France produced	440,000
In 1869, France produced	1,380,000
In 1845, Germany produced	180,000
In 1869, Germany produced	1,220,000
In 1845, Belgium produced	150,000
In 1869, Belgium produced	863,000
In 1845, Austria produced	175,000
In 1869, Austria produced	395,000

The total quantity of iron made in the world in 1869, varied but little from 11,700,000 tons.

The changes in the various modes of manipulating pig iron and advancing it to a finished article have been extraordinary and unexpected, and are still being made or attempted with a rapidity which it is difficult to keep pace with, and to which I have not the time to refer, even by name, but must omit mentioning, as I have done many of the slight changes in blast furnace operations.

For still greater improvements in making pig iron, aside from great discoveries of new principles, especially in this country, where, I am sorry to say, even the advantages already gained are not as fully seized upon as might have been expected, we must look to a more general and thorough knowledge of the principles which govern furnace working, a more intelligent combination of various ores, so to use as little flux as possible simply as flux, making different ores perform that function for each other, or using a proper flux where a separate material is really necessary; to the use of fire-bricks made from materials best adapted to resist the corroding influences of the ores to be worked, and to a general practical recognition of the fact that the production of pig iron is essentially a chemical operation on a huge scale, where even slight variations from the really best way are productive of enormous waste. The above objects can only be attained by frequent careful analyses of all the materials employed, and then by carefully modifying their proportions in a scientific manner.

In the mechanical portion of the labor of smelting there needs also the most thorough economy, not, however, always considering that an economy which is simply a neglect to do, in the preparation of the burden, from fear of the first cost, that which it really costs more to compel the furnace to do after the materials are charged in—such as roasting hard ores, thoroughly mixing ores, coal and flux, and reducing the pieces of each to the sizes proper for speedy action upon each other in the reduction zone of the furnace; also avoiding, as especially false economy, the hap-hazard way of charging, which is so frequent, for uniformity of action can only be secured by uniformity of means. I may perhaps be allowed to mention, as one excellent check upon this, the stock-house scales of Riehle Bros., which are on exhibition here, and which I know, from some years' use, to be extremely well adapted to that end. In our changeable climate, it may well be considered whether it is not also the best economy to protect, by non-conducting coverings, all pipes conveying steam or heated air, the loss by radiation being simply enormous, at many furnaces. Stock-heaps should be so arranged that the materials may be received and placed at the tunnel-head with as little handling as possible, bearing in mind constantly that pig iron is nearly all labor, and that it should be reduced as much as possible, not necessarily by a decrease of the rewards of labor, so that our men may be compelled to live in squalid hovels, with scarcely the necessaries of life, and none of its comforts, or, as Mr. Wells has shown the Belgian workmen, with meat, cheese, tea, eggs, fruit, and artificial light of any kind so seldom employed as not, all together, to form an item worth reckoning in the family expenses; nor need we aim at making the manufacture of iron exist, as a branch of national industry, upon the elementary condition of giving meat only once a week to its great mass of laborers, as Mr. Hewitt so tersely sums up the substantial state of affairs in France. But we should observe care-

fully the steps already accomplished in cheapening the production of iron, or, what is synonymous, the careful utilization of the utmost power men are capable of exerting over crude materials, to make the labor performed by every workman employed of sensible effect in accomplishing the final result, and, by carefully watching in what direction the observations already made and the principles already established are tending, see how they may be best made applicable to us and our country, that our magnificent natural resources may be made perfectly available, and the constantly increasing demand of our broad land be met from its own soil, and our own nation, instead of foreigners, permanently enriched by supplying it by the economical development of the treasures stored up beneath our feet.

What has been, and still is being accomplished in this direction, finds a partial barometer in this exhibition, a still more evident one in the rapid but wholesome growth of Troy, of Pittsburg, of Cleveland, and of the district about St. Louis, while, outside of towns, there is not a fertile farm in Pennsylvania which does not, by the high price put upon it, most powerfully indicate the advantages agricultural interests derive from the development of our mineral resources, and, simultaneously, point out the road Americans should wish to see America follow.

The statistics of the Lake Superior district will place vividly before you the most astonishing increase of the mineral development of our Northern border, within a little more than a decade of years; beginning with 1856, when iron ore was first mined there in any quantity, there were shipped 7,000 tons of ore, but not a ton of pig iron was then made there; in 1869, 633,238 tons of ore were shipped over the two railroads leading from that region, and 39,000 tons of iron were made; during these 13 years, 3,000,000 tons of ore, and 400,000 tons of pig iron have been brought from what, 20 years ago, was practically a wilderness. Still further West, the Northern Pacific Railroad will open up another region, where a similar history will be repeated. Missouri has already begun her race in the same direction of industry; the whole tier of Southern States only need complete restoration from the fever and delirium which began in 1861, and from which they are now convalescent, to pour out, from their northern frontier, such stores of mineral wealth as would make us gape with astonishment, had not constant employment of that faculty made wonder at any display of material resources in the United States almost impossible.

Notwithstanding my determination not to go beyond pig iron in treating my subject, I cannot forbear calling your attention to the surprising growth of our manufacture of rails, of which, 30 years ago, not a ton was made in America, the first rail having been rolled in 1843, while last year nearly 600,000 tons were made, more than half in Pennsylvania, and nearly 100,000 tons of it in New York, at Spuyten Duyvil, Troy, Rome, Syracuse, Elmira, and Buffalo, of a quality admitted to be far superior to the foreign rails generally brought here, and with which we are compelled to compete in price. The quality of our pig iron is also better than three-fourths of that made in England, yet the question of quality is usually practically ignored when discussing the question of sustaining, in America, the product of iron in any form.

The total supply of iron ores of all desirable qualities is practically inexhaustible. The heaviest known deposits, taking the country through, are almost untouched. In many of the easily accessible locations, where the deposits, originally worked, have been mined so deep as to make the ores too expensive for profitable working, new beds have been opened in immediate contiguity, so that no loss has been sustained, and in others some accidental circumstance or systematic exploration has developed new deposits which could be so much more cheaply worked as to cause the abandonment of the old mine, while yet the ore was as abundant as ever. I have a familiar acquaintance with a property within 2 hrs. ride of this city, which has been worked for more than a century, and which is so far from exhibiting signs of exhaustion, as to have yielded last year, as cheaply as ever, more than 80,000 tons of ore. A striking example of long continued yield are the mines in the Island of Elba, from which ore has been exported for more than 2,000 years, and which in 1867 yielded 60,000 tons of ore.

If the manufacture need not be limited from fear of exhausting ores and fuel, neither should there be any solicitude lest there be too much iron produced. The iron production of the world scarcely keeps pace with the augmented demand, and our country has never, since its political independence was achieved, made anything like the quantity necessary for its use, while the iron needed, per capita, is constantly increasing; so that to say that our make of iron is increasing faster than our population, and therefore it would perhaps be well to endeavor, indirectly, to check the growth of this industry, is, most emphatically, a fallacious course of argument. To compare very briefly our relative rate of consumption and production, let us glance for a moment at the metal required for rails, which absorbs the equivalent of half our make of pig iron. Since 1866, when we first fairly got breath after the close of the war, the demand for rails for new roads has increased about 10 per cent. per annum. Estimating the duration of rails at 10 years, which is certainly liberal, we have 10 per cent. more of the total quantity in use, required every year for repairs, in all an increase of 20 per cent. per annum; the American production of rails, in the same time, has increased 13 per cent. per annum, and in the make of pig iron there has been an average increase of less than 11 per cent.; showing that the manufacture of pig falls constantly behind the increased demand from the rail mills, and the manufacture of rails constantly behind the increased demand from the railroads.

As a mercantile adventure, it would perhaps be unbecoming in me to say that it don't pay to engage in the manufacture of iron, nor should I wish to convey the idea that we may not, some time, hope to see our iron-masters experiencing that prosperity which has made some of the iron-workers in Europe the wealthiest men in their respective countries; but I hazard nothing in saying that except during the war, when every business paid extraordinary profits, if there be fairly considered the capital employed and the heavy risks necessarily taken, the production of pig iron has never been largely profitable in the United States; and I desire here to say in reference to a statement, extensively copied by various newspapers, that a certain iron-work on the Hudson had paid 40 per cent. dividends, that many years before 1861 it paid *no* dividends, and finally, recently paid 40 per cent.—not on the capital actually employed, but, by the aid of its real estate, upon the original capital, which had lain a long time without yielding any return to those originally risking it. We may not hope for any sudden change from the generally very small profits furnaces are now making; but gradually, as labor becomes dearer in Europe, and capital cheaper here; as we, partially because of these changes lessening the risk of building extensive works, put up large furnaces, and are not compelled to adopt some inferior details of manufacture, because the best ones are, in the beginning, more costly; as we are able to command and gain the habit of employing the best scientific aids to our practical furnacemen; as by experience, also, we learn the best way of employing our ores, not staying away from the water until we know how to swim, lest we be always dependent on the boat some one else may or may not be willing to spare us, but continuing our efforts to learn, though at the expense of occasionally going under the surface, we shall finally achieve the success which, as thorough Americans, no less than enthusiastic iron-masters, we aim at, when we can not only profitably supply the heaviest demands of the home market, but be enabled to reverse our present position, and export, instead of importing this really precious metal.

Rumor states that the African diamonds are no better than the South African wines.

Buenos Ayres.—The Argentine Legislature has passed a law for securing an effective drainage, sewerage, paving, and water supply for Buenos Ayres. The works are to be carried out by a committee, with the assistance of an experienced and competent engineer. A credit of £60,000 per annum has been opened for the prosecution of the various undertakings proposed to be taken in hand; but unless a larger credit is authorized, the works contemplated will be 16 yrs. on hand, as their cost has been estimated by Mr. Coghlan at about £950,000.

ANCIENT EGYPTIAN ENGINEERING AND MODERN WAREHOUSES.

From "The Mechanics' Magazine."

In old days architecture and engineering were one; in these modern days they are, by our system of division of labor, separate. Architecture is one thing, engineering is another. The Lambeth Suspension Bridge is an example of pure and simple engineering, *i. e.*, pure and simple construction without the addition of any element of fine art; and the great question therefore is—and it is one of the most important of all modern questions, for it includes so much—what is the value of pure construction as an element in art, and how best may it be improved, and is it to be improved by the addition of forms from the antique and the past, or is it to be verified by the addition, and what kind of addition, of anything from things as they now exist, and as they pass around us? This is the art question of the time, and there surely can be no more interesting subject to the student of engineering, for must he not naturally desire to influence if possible the art as it appears in construction of the age he lives in? To help him to do this we propose to offer a few hints on a new method of wo k, and to contrast it with the present and past systems of work.

Before we do this it will be necessary that there be some definite notion of the old system of work, or in other words of the old architectures, which were, indeed, nothing more than the construction of the times, ornamented by the art peculiar to those who employed that construction, whatever it may have been, and this it will be found was all got without exception from the living art and nature of each special country and age and people. It must at the same time be always borne in mind that not only has the art as fine art and method of ornament changed from age to age, but that the systems of construction have changed too. Before the invention or accidential discovery of the arch of course it could not be employed, and it would be not a little curious nowadays to see a town or city entirely built without any use whatever of arch construction; but time was when the absence of the arch was universal, no arch forms were anywhere visible, all construction and covering in was by means of straight beams or "lintels." It will be convenient to bear this in mind as a not inapt division of architecture into two divisions or orders—the arch order and the lintel order. This simple division will be found to conduce, if kept in mind, to clearness of apprehension.

We do not propose to go into all the several phases which these two systems of architectural construction have passed through in the different countries in which they have appeared and been practised; but we must, to make things clear, and to show how much there is yet for a future generation if not for the present to do, cite one or two examples of one or two of them, and then hint, as we go on, at the uses which might have been made of such examples by modern engineers had they but have known of them. Whatever may have been the difference between the ancient and modern systems of doing work, of one thing there can be no doubt, that at no time in the world's history has there been more building than at the present time, or greater opportunities of doing great things and impressing on such building some stamp of modern and nineteenth century life, and of conveying to distant times some material idea of what our present life is like, and what it is worth as contrasted with the life and ways of Athens or Rome, of Persepolis or Babylon, or of the great cities and towns of France and Germany in the middle ages, or of our country in bygone days.

To get a tolerably clear idea, then, of such an architecture or system of construction as that of ancient Egypt we must first bear in mind that all there was of it, whether much or little, was Egyptian, and nothing else—there was no borrowing possible, it was all the work of the people themselves—and that all that we now see of Egyptian art and architecture was, for anything that we can tell or see, entirely their own, and their own invention. How long it took to grow up from its beginnings and develop itself is indeed a difficult question and perhaps impossible to answer; but of this we are quite certain, that it was purely the Egyptian's own work and his only, and did not come of any foreign source.

Now this, if we come to consider it a moment and without prejudice, is a truly wonderful thing, for how any one single nation, however great it may have been, could have done such marvellous works without foreign help and by themselves is indeed surprising, when we consider how much we nowadays owe to foreign help, and but think for a moment where we should be without it. Fancy for an instant what would the modern architect or engineer or even common house builder do nowadays without precedent of any kind, with all his materials on the ground and workmen ready and able to work, but he himself without book guides, or in other words foreign help, or, in still plainer words, without bygone architectural and artistic forms and methods of work to go by, whether Classic or Gothic. What would the modern man do? No one can answer this question, nor can anyone see his way to any sort of answer to it. But this was the state exactly of the old Egyptian engineer; he had nothing to go by but what he had in himself, what there was about him in actual life, and the dead materials on the ground waiting to be wrought into the form and semblance of something, and to be impressed with some special character.

And again—and this must not be forgotten—the old Egyptian had in our sense of the word no science, none of that science which is now altering the very face of the globe itself. He quarried the stone blocks which afterwards formed the walls of his temple, but he knew nothing of where they originally came from, or how they were primitively formed. He knew nothing of the "mechanics of engineering," of the steam engine, or of any of those wonderful forces which now form the study of so many, and which puzzle so many more, and a knowledge of whose action will in the future change the very thoughts of men, their aspirations, and their hopes. He knew nothing but of the materials dug from the earth, the very simplest laws of construction, or rather practical methods of construction, and the art which had grown up in his own country, and which was peculiarly his own. He knew also the necessity of employing personally those who were gifted with the power of impressing on the unformed and rough materials the proofs of their own individual artistic skill. Nothing could possibly be simpler or more self-evident, and it is not a little surprising and certainly not less instructive to compare the work of the old Egyptian thus simply provided, with that of our modern railway works. There is, as we all know, nothing in modern times so large and impressive as the works, whether of building or civil engineering to be found in and about railways. They are the only things that can for a moment compare in extent and magnitude with the temples of the ancient world. All our modern churches and chapels and the buildings connected with them, all our house or even palace building is but poor work, as mere building, compared with Egyptian temple architecture and engineering; and the wonder is how such work could have been accomplished with the slender mechanical means which they who built them possessed. It would puzzle even our civil engineers to raise and put steadily in their places, and without breakage, such vast masses of stone as were necessary to reach from column to column in the Egyptian temple architecture; and still more would it perplex them to fit them so nicely into their places, and with so fine a mortar joint, and beyond them altogether to so do the work as to make allowances for the "eye line" as it is termed, that is, to so curve the stone as to give it its true proportion to the eye, and to make of the mere line of a rule an artistic one. With such vast masses of stone to deal with, this is indeed noteworthy. We have nothing like it, or indeed any approach to it, and we mention it to show how little of anything that can truthfully be called an advance or improvement has taken place during the many ages which have elapsed since the days of the Pharaohs! And all this be it observed without our mechanical appliances and scientific apparatus and cranes and steam engines.

We have mentioned those works to be found in London, the works of the civil engineer, which are, as we think, remarkable for the absence of architecture or fine art borrowed from the past, and, so to speak, fixed on to it as by afterthought; for it is in such works that we may be said to find ourselves in the precise position of the old Egyptian engineer, we are fairly left to ourselves without precedent or anything to go by to make or create art or architecture as it is called. We

have named several of these works, and we might add to them the great blocks of warehouses which line the banks of the Thames, particularly those newly built below bridge on the Surrey side of it. Any one going through the long lane called Shad Thames may see what modern men can do with mere bulk, for some of these warehouses are of the most solid materials, and some 80 ft., 90 ft., or 100 ft. high; the walls of great thickness, the floors of solid and massive timbers, and the roofs fireproof and of the most improved construction. No expense has been spared, yet who will venture to say that this long line of tall buildings, massive as they are, have any sort or kind of dignity or art, or architecture, or beauty, or even interest in them? They are simply four walls with windows and roof, built up to hold goods, yet by altering a little the main lines of them, and the direction of their roofs, and giving a little thought to the windows, these huge buildings might have been made really artistic, and the whole line of street—and we still refer especially to the narrow street bordering the river to Shad Thames—might have rivalled in dignity and interest any thing to be found in countries whose history is passed away, but which have left so many memorials of their power over the rough materials which nature provided for them. We mention these warehouses in addition to railway works of which indeed they are sometimes a part, first, because they are the work for the most part of the civil engineer; and secondly and chiefly, because they are not architecturally ornamented, nor has any effort been made to make them look like palaces by ornamenting them with architectural details taken from Venetian palace architecture, or from French cathedrals or street mansions. In Egypt, it may be observed in passing, the house architecture would seem to have been of the simplest kind. The great efforts of the engineer and architect were confined to the palace, temples, and pyramids, and river terraces, so that the art of old Egypt was of a very democratic character indeed, and employed for the good of all, and open to the eyesight of everybody. In our more advanced and improved days the poor public see but little of fine art, for it is all in the interior of our buildings, and those buildings are almost always private property, and so visible to none but their owners. The Lothairs of modernism do not care to exhibit their art splendor!

LOCOMOTIVE IMPROVEMENT.

From "The Engineer."

In our last impression we endeavored to show that no improvement in the comparative efficiency of the locomotive boiler can be expected as long as the existing type is retained in its integrity. This argument is based on the fact that the modern boiler being no better than the boiler of 10, 15, or 20 years ago, it is hopeless to expect any further improvement. It is, of course, just possible that the able engineers who have devoted their attention to designing locomotives have one and all suffered those features in which improvement could have been effected to escape them; but this theory is to the last degree improbable. We hold, therefore, to our statement that unless some radical change is introduced in the construction or working of locomotive boilers, we are not justified in reckoning on any better result than an average evaporation of some $6\frac{3}{4}$ or 7 lbs. of water per lb. of coal burned. What the radical change in construction and working is to be we are unable to say positively, but we can at least indicate the nature of the alterations which are likely to prove advantageous; and it is to be borne in mind that although these alterations may be very radical and thorough in their character, it does not necessarily follow that the general characteristics of the boiler, at least as regards external form, need undergo much change.

In former articles we have explained the points in which the ordinary portable engine boiler constructed by agricultural engineers is superior to the vertical boiler, but the statements we have made with regard to portable boilers will not hold

good for the locomotive boiler. We have deprecated to a certain extent any innovation on ordinary portable boiler practice, but we cannot deprecate innovation on ordinary locomotive practice. The principal causes of the low economical efficiency of the locomotive boiler are inefficiency of surface, want of circulation, and rapidity of draught. The tubes in locomotives are packed so close that the presence of good circulation is almost out of the question; but the tubes in portable boilers are so widely spaced that the circulation ought to be, and doubtless is, much more efficient. As regards the second point the draught is much less energetic in portable than in locomotive engines; and for any given length of flue the products of combustion are suffered to remain a longer time in contact with the iron. Lastly, the temperature of the water in portables being much lower than in locomotives, an element of economy is secured in the first which is lacking in the latter. We shall not extend our comparison between two boilers so apparently similar in type, but totally dissimilar in working conditions. It will, we think, be found, on close examination of every point connected with the two boilers, that the similarity between them is apparent only; and that it is simply impossible to argue from the results obtained with one, what results ought to be obtained with the other. We may, therefore, dismiss the portable boiler for the present. We have spoken of it here only to guard ourselves against the possibility of being accused of inconsistency by those who think proper to read these articles with those which appeared in our impressions for July 29th and August 5th, 1870.

Before we can hope to improve upon the existing locomotive boiler, it is absolutely essential that we should thoroughly comprehend the nature of the defects which it is proposed to eliminate. What these are we have just stated in general terms. But many people speak of the phenomena of defective circulation, inefficient surface, and forced draught, without possessing any accurate perception of the way in which these defects really operate for evil. We shall endeavor to place these matters in the clearest possible light, and to draw some conclusions which, at the same time that they are, as we believe, unavoidable, will not fail to suggest a means of improving the evaporative economical efficiency of the locomotive boiler.

First, as regards inefficiency of surface. This simply means that the tubes and fire-box plates become coated with scale, which, being composed of sulphate of lime and other salts, and earthy matters, is a very bad conductor of heat. The effect of the presence of this deposit on the tubes and fire-box is that less heat can escape in a given time from the products of combustion into the water than would be the case if the deposit were not present. In effect, deposit virtually reduces the length of the tubes and diminishes the size of the fire-box. It is not certain, however, that deposit in moderate quantity diminishes the *actual* efficiency of a steam boiler. Peclet has shown that iron boilers evaporate just as much as copper boilers in a given time, although the conductivity of copper is nearly double that of iron, because, to use Peclet's own words, "When the thickness of a metal is augmented, its conductivity is diminished, but the temperature of its external surface is augmented in just the same proportion." "It is believed that, as the quantity of heat transmitted augments with the temperature of the exterior surface, the influence of the kind and thickness of the metal is very trifling." Peclet then goes on to furnish proofs in support of this belief, for which we must refer our readers to Peclet's "*Traité de la Chaleur*," *tome premier*. Again it must not be forgotten that the quantity of heat passed in a given time through a plate depends much very much more on its power of absorption and emission than on its power of conducting. The precise meaning of this statement will be found very clearly set forth in a paper on "Water-tube Boilers" read before the Society of Engineers on the 6th of May, 1867.

Now we do know that deposit directly affects the conducting power of a tube, but we do not know whether deposit increases or diminishes its emissive power. It is possible that a coated surface will emit more heat than a plain, smooth metal surface, because the coat of deposit is rough, and the roughness may aid the formation of steam like the coil of silver wire on the little bits of pure coke used by chemists to obtain equal

ebullition in laboratory experiments. But whether it does or does not, it is certain that the direct effect of anything more than the thinnest possible coating of deposit operates prejudicially. It does not follow that the actual energy of the boiler as a steam generator will fall off. The temperature in the tubes is augmented and the same quantity of heat finds its way per second or per minute into the boiler, but this result is only obtained by harder firing; in other words, by burning more coal. The dirtier the tubes and fire-box the higher will be the temperature in the smoke-box, and of course the greater the waste.

And here it will be well to notice an objection constantly urged by those who believe in the excellence of the locomotive boiler, which may be thus stated: "The boiler can only be uneconomical by wasting heat, but if it wastes heat, that heat will be found in the smoke box; it will manifest its presence in the high temperature of the escaping gases. But there is not a high temperature in the smoke-box, therefore heat is not wasted." This is a very logical proposition, which breaks down only at the end. No one knows accurately what the temperature is in the smoke-box. So long as an engine is not heavily taxed and the draught is moderate, it is indisputable that the temperature, especially if the tubes be long and small, is low; and there can be no question that engines moderately loaded and running at low speed evaporate more water per pound of coal, provided combustion be perfect, than does an express engine careering across country at 50 miles an hour with 10 or a dozen heavy carriages behind it. The boiler quickly falls off in efficiency as the quantity of coal burned increases, and this is no doubt one reason why the cost of transport increases so rapidly in proportion to the speed, albeit it is one which has not received half the attention it deserves. But to return to facts connected with smoke-box temperature: Stephenson's experiments made in the neighborhood of Derby, in 1843, showed that in the ordinary locomotives then in use the temperature in the smoke-box was great enough to drive zinc off in vapor; and this metal requires a temperature of not less than 800 deg. to melt it. As a result of these experiments, Stephenson introduced his well-known "long boiler" locomotives, many of which are still running on the Great Eastern and other railways, with tubes nearly 14 ft. long. The evidence usually adduced in opposition to the idea that a high temperature exists in the smoke-box, is based on the fact that the black paint put on outside lasts a long time; but this is not good evidence, because, first, the inside of the box is always lined with a thick coat of soot, which is an admirable non-conductor; and, in the second place, the smoke-box plates are exposed to the action of a violent current of air, which increases in its effect with the speed of the engine. Besides this, there is little doubt but that the products of combustion operated upon by a powerful draught rush direct from the tubes to the chimney, and are, therefore, drawn away from the sides and front of the smoke-box, which is always some inches larger than the barrel of the boiler. The wonder is, considering the cooling effect of the external air, that the paint is ever burned off a smoke-box at all. But it is none the less likely that the temperature within frequently reaches, or perhaps exceeds, 800 deg., or at least 450 deg. more than the water within the boiler. As the draught is dependent on the exhaust, and not on the temperature of the escaping gases, as in stationary boilers, there is no reason why the temperature in the smoke-box should exceed that in the boiler. The only method of even approximately obtaining that result as yet used by engineers consists in lengthening the tubes; but this plan is always attended with the disadvantage of rendering a smaller blast pipe—and consequently an increased back pressure—necessary to maintain the draught. It remains to be seen whether other remedies may prove more effectual.

It is to be regretted that no accurate experiments have been made to furnish us with data as to the precise loss of efficiency due to the gradual accumulation of deposit on locomotive heating surfaces, but enough is known to prove conclusively that a great point would be gained if it were possible so to construct the boiler that either no deposit could form, or that the boiler could be taken to pieces and thoroughly cleaned, say, once a year. Our readers will, we think, admit unanimously that the presence of either one

or both of these conditions in any boiler proposed as a substitute for the ordinary locomotive boiler would be a strong point in its favor. We may have something more to say about this further on; just now we must turn to the consideration of the second defect in the existing boiler—want of circulation. About the rapidity of escape of the products of combustion little more need be said than we have stated already. It is impossible to reduce it without augmenting calorimeter, which cannot be done under existing arrangements. Whether it can be done at all with success, or whether it is necessary it should be done, are points the consideration of which we shall reserve for the moment. As regards the question of circulation in locomotive boilers, it is difficult to speak without using as an illustration of our meaning an explanation of what appears to us to be the only available method of making it really efficient, and this deserves an article to itself. However, we may say something which will lead up to the article to which we refer.

Most engineers admit freely enough that the circulation in locomotives is not what it ought to be. Yet in practice we find them cramming their boilers as full as they will hold with tubes. Half-inch spaces are by no means uncommon, and some French engineers have stowed their tubes but .44 of an inch asunder. We have heard it argued, and by good authorities, too, that the reason why locomotives so made are not economical and burn their tubes, is that there is not water enough in contact with each tube—in other words, that the thickness of $\frac{1}{4}$ of an inch of water is not enough to take up all the heat passed by the tube. No greater mistake could be made. The true objection to the close stowing of tubes lies in the fact that the steam as it is formed on the tube surface cannot get away, and as a result it is steam, not water, that is in contact with the metal. Water is an excessively bad conductor of heat, but is perhaps the most powerful absorber of heat known when properly used. The close stowing of the tubes would matter nothing if only we could get rid of the steam, but this we cannot do so long as we dispose tubes in such a way that the area of escape is contracted and interrupted to the least degree, while no sufficient means are provided for sweeping the bubbles of steam off the tubes. A strict analogy exists between the boilers and condensers, and it may be taken as proved that *within certain limits* the quantity of steam which can be condensed by a given surface is altogether independent of that surface, and absolutely dependent on the quantity of cold water brought in contact with it in a given time. In the case of boilers much the same truth holds good. If we take a thin metal pipe and pass it through the fiercest furnace which it is possible to get, that tube cannot be over-heated, provided enough water is sent through it in any given time. Extension of heating surface is neither more nor less than a substitute for defective circulation and absorption. To put this more plainly: If we have two plates of metal, each exposed on one side to the same temperature, and each in contact with a given quantity of water on the other side, then by doubling the quantity of water brought into contact with one we may practically double the efficiency of that surface as compared with the other. It is to be borne in mind that if the original quantity of water in contact with each plate is great enough to absorb all the heat it can have, then of course our proposition will not hold good; but this is not the case with locomotive boilers. The tubes there are in very much the condition of a saucepan on a fierce fire with but a spoonful of water in it, not sufficient evenly to cover the whole bottom. If this spoonful be kept constantly renewed as evaporation goes on, still the saucepan bottom will not generate as much steam or do as much work as would the bottom of another saucepan on which a jet of water continually impinged. The film of water might be of the same thickness in both cases, but in the latter all the steam bubbles would be swept away, while in the former they would continually intervene to prevent true contact between the metal and the water. It is not the deficiency of water, but the presence of steam between and in contact with the tubes, that impairs the efficiency of the locomotive boiler with close stowed tubes. If only we could dispose of the steam, we might put our tubes $\frac{1}{8}$ of an inch asunder, provided we could command means of clearing the tubes of deposit. It is simply impossible, however, to get rid of

the steam as fast as it is formed in locomotives with close-packed tubes. How, then, is the objection to be got over? The answer is this, and embodies so important a proposition that we put it in italics: *Do not allow any steam to be formed between the tubes;* and we shall put this in more general terms by stating that *every boiler, locomotive or other, in which it is intended that the heating surface shall possess a maximum efficiency, must confine its functions to the heating of water, not to the direct production of steam.* Under no circumstances should steam be directly produced by any heating surface, unless means are provided for removing that steam immediately. We propose to show, in a third article, how it is possible in practice to apply principles, the soundness of which was recognized in an indistinct and misty kind of way many years ago.

BOMBAY TO CALCUTTA BY RAIL.

The following from the "Times'" correspondent, dated Bombay, Sept. 7, gives an interesting description of the journey across India by railway:—

I have just made a rapid run across India, from Calcutta to Bombay, in 62 hrs. The time occupied by the mail trains at present is 68 hrs., but in a few weeks the opening of the Chord line of the East Indian Railway will reduce the time to 64 —a little more than 2½ days. All the arrangements are admirable. On both of the Great Indian and East Indian lines the mail train runs at 25 miles an hour with great punctuality. The refreshment rooms are wonderful for India, but the careful traveller can always make himself independent of them. The sleeping carriages for the first-class on both lines are comfortable enough, but those of the Great Indian are superior to the other lines. Were the second-class carriages of the East Indian Railway Company half as convenient as those of the Bombay line, I would recommend all gentlemen at least to use them. They are cooler than the first-class, and the charge is just one half. From Bombay to Calcutta the first-class fair is about £15, and the second-class half of that, but the charge for luggage is heavy. The great rush of passengers through Bombay to all parts of India is just beginning, and, on the whole, the railway companies are prepared for it. Even at present ladies may travel comfortably, and in India one soon becomes accustomed to long journeys. But in a few months American palace cars will be placed on both lines, when the journey will be almost luxurious for those who care to pay a slight addition to the first-class fare. Passengers landing at Bombay in the morning may take the mail train at noon, thus avoiding hotel expenses. Those who must spend a night in Bombay or desire to see the island will find improved hotels. A gigantic iron structure is nearly finished on the Esplanade, having cost £70,000 already. It stands midway between the Apollo landing pier and the Boree Bunder terminus, and is in the centre of the new city, of which it is hardly worthy. All train arrangements have now to be made to avoid traffic on the Thull Ghaut at night. There is little risk, but one serious accident has already occurred. In the library and reading-rooms of the Asiatic Society, in the Town Hall, and in the fine institute which bears the name of the Jew merchant prince, Sassoon, near the hotel, the visitor will find all the most recent periodical literature, both Indian and European.

I was enabled to anticipate the opening of the Chord line, and to run along it at the rate of 30 miles an hour, by the courtesy of Mr. Perry, of the contractors' firm of Messrs. Brassey, Wythes & Perry. There is no reason, so far as the contractors are concerned, why the line should not have been opened months ago. It is in a much more forward state than the portions on either side which the East Indian Railway Company are doubling, and even than the Jubbulpore section of the Great Indian line, which Lord Mayo and the Duke of Edinburgh formally opened last March. The main line follows the tedious detour of the Ganges, in order to accommodate the traffic of the valley and its great cities. The Chord line cuts off a distance of 3 hrs. in the journey between Calcutta and Patna. It leaves the Raneegunge coal branch, henceforth to be

the main line, at Seetarapore, and joins the old main line, at Lukeeserai below Patna. The whole distance is 147 miles, of which 123 are trunk, and the rest form a branch to the fine coal fields of Kerhurbalee, which the East Indian Railway Company are to work for their own supply. Messrs. Brassey, Wythes & Perry obtained the contract for £1,250,000 sterling, the Company to supply the permanent way.

The total cost of the line will probably not exceed £13,000 a mile, although it has been laid in a difficult, rocky country, comparatively destitute of population. The line should have been opened at the beginning of this year, and Lord Lawrence offered a bonus for its more speedy completion. But the land was not made over for 8 months after the beginning of 1866, there was no material for bricks, and the railway company have in many instances delayed to supply the permanent way. The marvel is that the line has been finished so soon in the face of such obstacles, physical and administrative. Almost all the labor had to be imported, cholera more than once scattered the gangs, and tigers carried off many a workman in the jungle country. The works display the finest and heaviest rock cutting in Eastern India, almost worthy to be ranked with that of the Thull and Bhore Ghauts in the Bombay Presidency. Of the 123 miles of trunk line no fewer than 40 consist of deep rock cutting. Leaving Seetarampore on the way to Bombay, the country differs little from the undulating coal deposits of Raneegunge till the first three stations of Meeja, Jamtara, and Seetacotta are passed. Soon we approach the heavy embankments and cross the fine bridges which span the Jyntea and the Puttro tributaries of the Adjar river, now swollen by the season's rain. To the north the Beerbhoom hills, the last outcrop of the Vindhya range which crosses India, tower aloft. To the south is the grand trunk road, with the little sanitarium of Parisnath, sacred to the Jains, rising suddenly from the jungly plain. We reach Mudoopore, the changing station for the Kurhurbalee coal fields, 24 miles off, and for Parisnath, 16 miles to the south of the branch terminus. It is to be regretted that so little has been done at Kurhurbalee in raising coal or preparing the shafts and machinery. Until a railway has been opened to Darjeeling, it is likely that this part of the country, and especially Parisnath, will become a retreat for invalids and holiday-makers from Calcutta as Matheran is from Bombay. We are now in the Santhal country, the scene first of rebellion, provoked by our own folly, and then of mutiny. We cross the Adjar on a bridge of 10 spans of 84 ft., with piers resting on rock 40 ft. below the bed of the river, pass Rohinee, where Macdonald fell a victim to the native cavalry, and reach Byjuath, 3 miles from the sacred shrine of Deoghur, to which so many pilgrims flock. What a change has passed over the country from Rajmahal to Deoghur since the local rebellion of 1856! Sir George Yule's patriarchal administration, followed by the two railways, has delivered the simple Santhals from the bonds of the Bengalee usurer, although they still consider it both prudent as a precaution against years of famine and a sign of respectability to keep their names on the money-lender's books for a few rupees.

Cultivation has greatly extended in the last few years, for the people are becoming comparatively wealthy, and they have now found markets for their produce. They are crying for schools, too, and the missionaries are fast converting whole villages of drunken and unchaste peasants into good Christians. We leave the picturesque Santhal country for the plains of Monghyr by the Nargunjoo Pass, a magnificent cutting of 5 miles, on which for 4 years some 5,000 men have been daily engaged, and 240 lbs. of powder have been daily used. At this season the whole pass resounds with mimic waterfalls. It is green from the summit, and ends in a pretty lake, which the engineers are turning to good use. We soon dash through the changing station of Newadee, through Mulleepore and Etone, to Lukeeserai, and catch the mail train, which has been so much longer on the road. It is not probable that this Chord line will add to the shareholders' dividends for a long time, if, indeed, it does not diminish them at first. But it has opened up a fine country teeming with mineral wealth and with endless agricultural resources. The line has been as solidly constructed as any in India, for at the close of a season of heavy rain the new embankments and bridges were perfect.

RELATIVE ECONOMY OF COFFER-DAMS.

From "The Mechanics' Magazine."

Notwithstanding that timber has for some time been almost totally superseded by iron in all works partaking of a permanent character, yet the older material is still extensively used in all those of a temporary nature. Among the latter the three largest examples are to be found in scaffolding, staging, and centring for bridges and coffer-dams. A practical illustration of the first is to be seen, or rather was a few months ago, on the site of St. Thomas's Hospital. The new bridge at Blackfriars afforded a splendid specimen of the second, and the walls of the Thames Embankment fully proved to what an extent the third could be carried. Many persons who observe in a cursory manner only the bewildering array of huge balks of timber, half timbers, stays, struts, and braces of every size and description that constitute the *tout ensemble* of a large temporary wooden structure, come to the conclusion that there is very little method or system in the arrangement. But upon a closer examination, especially if that examination be conducted by a professional man whose eye is capable of discriminating between multiplicity and confusion, the whole massing together of the timbers will prove to be in accordance with well-known scientific laws of combination. Each particular component part will be found to have its own especial duty to perform, and in the accurate allotment of these several duties and in the proper proportioning of the various parts, lies the whole economy of the temporary structure. When constructed in a scientific manner a very little timber will go a long way, whereas a whole forest might in some instances be exhausted without yielding the strength and rigidity so much required. It is not the quantity of timber employed that constitutes the security of the structure, but the positions in which the various uprights, together with the ties and cross bracing, are placed. Very frequently a large amount of timber is completely sacrificed by being placed where it is of little or no use, while the safety of the structure is jeopardized by the absence of it at other points where it is urgently needed. If the timber used in temporary works be divided into the three classes of vertical, horizontal, and inclined, the largest sticks will generally be included under the former two. The inclined pieces comprise the individual components of the bracing, consisting of struts and ties, which from the different manner in which they are affected by the strains, can be composed of smaller or half timbers. When the temporary work has any pretension to magnitude the vertical and horizontal beams are mostly all whole timbers. They are generaly of as large a scantling as can be obtained for the purpose. It is always desirable to procure the balks for the uprights in one length when possible. When this cannot be done they must of course be scarfed.

The relative economy of substituting iron for timber in temporary works has been very much discussed among engineers and contractors, but as yet no decisive conclusion has been arrived at. There are so many points to be considered, and the instances which occur in actual practice present so many features of diversity, that the application of a general rule appears to be well nigh impossible. In the first place, the economy does not depend upon the fulfilment of one, but of several conditions. There is the first cost of the two materials to be taken into consideration, then the cost of erection, of maintenance, and subsequently when the temporary means have accomplished their work, that of removal and ultimate disposal. It is rare that a case would happen in which all these contingencies would tell favorably with respect to one material and prejudicially to another. If that were the state of affairs the question would have been determined long ago, and there would not be the slightest necessity for entering upon it. Our comparison at present rests between the adoption of iron, timber, or other materials for coffer-dams. Everyone is acquainted with the construction of an ordinary timber dam. That used for the Thames Embankment will serve as an example, and there are probably but very few of the inhabitants of the metropolis who have not, at some time or other, had an opportunity of inspecting it, either from one of the bridges spanning the river or from a boat on the

river. As a full description of the dam on the Middlesex side of the Thames is to be found in our columns of last week, we shall not recapitulate, except when necessary for the purpose of illustrating our comparison. There are four principal methods which may be employed in the construction of dams. Firstly, they may be made altogether of earth and such excavated materials and *debris* as can be procured near at hand. This is unquestionably the cheapest kind of dam that can be constructed, provided always that the material can be obtained within a moderate distance from the site of the work. Unfortunately this condition is very often quite impossible of fulfilment, and the difficulty of so doing is enhanced by the fact that a dam of this description requires a larger amount of cubical material than any other. It is, cubically considered, the largest dam of any, as it has nothing to depend upon for support but its own inherent weight and stability. For permanent works such as the Thames Embankment and reclamation of land from the sea, this kind of dam is admirably adapted, but for the reasons given it is not suitable for works of a temporary character. The large area of ground it would occupy would be a serious obstacle to contend against. There is another feature which is also disadvantageous to it; it is that in order to bestow upon it those attributes of strength and solidity which must necessarily belong to it, a comparatively long time must be occupied in its construction. It is a dam that must be made up very slowly. In fact, the slower the better. The more time afforded for the incorporation and consolidation of the separate layers successively superimposed, the more firm and consistent is the whole rendered. It is needless to point out that a dam of this description is an impossibility in situations similar to that of the Thames Embankment. The material could not be obtained, the area of ground on which to build it was not procurable, and the necessary time could not be afforded. Under these circumstances it was imperative to adopt some other method of construction.

The second description of dam which we propose to consider is that best known and employed, it may be said, from time immemorial. It consists of a double row of piles, enclosing a puddle wall in the intervening space, and shored and strutted with timber as necessity may require. In this case less ground is needed than in the former, and also the earth is limited to the supply necessary to form the puddle. But although the quantity of the earth is thus very much reduced, the quality demanded is of a very superior kind. Common excavated stuff will not answer. Good clay must be obtained, or the dam will fail in the most essential point—that is, it will not be water-tight. Those who are aware what an expensive item pumping constitutes in all similar temporary undertakings will be able to judge of the importance of this particular. In spite of all precautions leakage is certain to ensue from the shrinking and contraction of the puddle, as well as from other causes. At the Thames Embankment dam pumping to a greater or less extent was carried on until the water had risen to 6 ft. above low-water mark. The maximum volume raised per minute amounted to 1200 gallons, and the minimum to about half that quantity. In all dams of this kind the introduction of the puddle element is a serious source of expense, for if we select, as another example, one in which the piles are replaced by earthen slopes, while the puddle and half timber shoring are retained, there is very little saving effected, and under certain conditions there would be none at all. Classing all dams under the heads of puddle and non-puddle dams there remains to be considered that description in which the combined effect of the ordinary piles and puddle is obtained by the employment of either wrought or cast iron caissons, that is, by the substitution of iron for timber. Some amount of timber will be required for the shoring, which may be regarded as common to both methods. The use of the caissons obviates the necessity for the somewhat precarious labor of driving piles, and the dredging can be carried on with equal, if not with greater facility. Unless ordered beforehand there is more difficulty in obtaining caissons than piles, as there is a perpetual demand for timber, whereas the former are not yet employed to an extent that justifies their being kept in stock. In certain situations we should give the preference, on the score of economy, to the caisson system.

There is one point which, in comparisons of this nature, is invariably overlooked and disregarded; it is that the different estimates cease with the erection of the temporary work. This is only doing the thing by halves. The removal of a dam and the ultimate disposal of the materials used in its construction is intimately connected with the whole question of its relative economy, and will frequently serve to turn the scale in the very opposite direction to that to which it would incline when the comparison is based on the former calculation alone. So far as dams constructed wholly of earth are concerned, the cost of their removal will be nearly equivalent to that of their erection. If there are no hollows in the vicinity to be filled up, and the material cannot be shifted into the excavation whence it was originally taken, all further consideration of it may be abandoned. Similarly with puddle dams, some provision must be made for running it to spoil somewhere, or re-utilizing it in some remunerative manner. The great plea put forward by the advocates of the caisson system is that the caissons can be used over and over again, as they are not in any wise injured or deteriorated by their temporary duties. Theoretically this assertion is correct, but it is nevertheless one thing to prove that a material can be used and another to use it. Unless a use can be found for it the mere possibility of employing it is of little avail. If a contractor had a succession of works on hand requiring the construction of temporary dams, so that as soon as one had done its duty there was an immediate demand for it elsewhere, iron caissons would prove invaluable to him. But this is never, or at least very rarely, the case, so that under ordinary circumstances the caissons might lie idle, especially in the present famishing condition of the profession, for years. A glance at the collection of plant arranged for sale by auction on the Embankment near Waterloo Bridge will indicate that iron caissons are not in such request as to cause them to prove very profitable for re-selling. Still it may be urged that the caissons can be utilized, whereas the timber used in a dam cannot. This latter statement is not altogether quite valid. It is true that as the piles have to be cut off not very far from the ground line instead of being drawn, the most valuable part of the timber is lost, as the remainder is a good deal damaged by bolt holes, straps, and the necessary fastenings. But it is a mistake to suppose that on this account it is altogether profitless. Most of it is of large scantling and in long lengths, and is always available for cutting up, and so long as it is sound in quality there is generally a market for it. There is no necessity for it remaining, similar to the caissons, long on the contractor's hands. If he cannot use it himself he will find plenty who can, and be glad to get it at the price. Second-hand timber of this description, if in fair condition, is worth a shilling per cube ft., or very nearly so. In selecting the particular description of dam to be used for any work, the details should be left to the contractor, subject to the approval of the engineer, as the former is the best judge of that which will turn out the most economical construction upon the whole. It is a very unwise proceeding to insist upon the contractor adhering to any especial means for accomplishing his own task. So long as he does accomplish the permanent work in a satisfactory manner and according to the specification, he should be left at perfect liberty to steer his own course, and be acquitted or condemned, not in the means, but in the end. No contractor objects to the most vigilant superintendence of the engineer, but he does decidedly object to the least officiousness or attempt at meddling with either the methods he pursues or the men he employs.

The Brooklyn Caisson of the East River Bridge reached its final resting place on the 21st of December. The lower edge is now 45 ft. below mean high water.

Steam Dummies are used on the elevated railway in Greenwich street, instead of the endless rope heretofore employed The success of the present experiment is not yet assured.

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THE RECENT DEVELOPMENTS OF COSMICAL PHYSICS.*

* Extracted from a Lecture delivered at Owens College, Manchester, introductory to the Session 1870–71, by Professor Balfour Stewart, LL.D., F. R. S.

From "Nature."

There are two conflicting theories with regard to education. The extreme partisans of one of these would have us believe that the great object of education is not so much to inform as to discipline the mind; the subject taught in a seminary may not in itself increase the student's real knowledge, yet if it tend to discipline his mind, it has proved its value in their eyes as a branch of education.

According to the upholders of this theory, our object in going to school is to leave it with a mind enlarged in its capacity for acquiring knowlege rather than stored with knowledge itself; having trained the soldier well they would send him without scruple into the enemy's country, not only to fight his own way but to find his own weapons.

But there is another and opposite class of theorists who regard education not as an agent for training the mind so much as a means of storing it with knowledge. The extreme partisans of this theory would teach the student nothing but what is of apparent and immediate use; above all things they would teach him the sciences, both in their principles and also in the various details of their application to the industrial arts of life.

The mind of the student who has undergone a training of this kind carried to its extreme, resembles the inmate of a house which is not so much well furnished as filled full of furniture. In the accumulation of mere material, anything like plan or principle has been forgotten. It ought to be remembered that the value of a fact lies not in its existence somewhere in the mental storehouse, but in the readiness with which the mind can find it when required.

Now between these two extreme theories it is surely possible to steer a middle course; it is possible to avoid grounding on Scylla without being swallowed up in the vortex of Charybdis. In the material world, what would be said to a man who insisted upon developing bodily strength by a course of gymnastics without reference to food, or of another who insisted upon doing the same by a course of diet without reference to exercise? But is the separation more natural in the mental world? Is not that mind most perfectly disciplined which is at the same time most perfectly informed? The student who has been disciplined by only one branch of knowledge is, I venture to think, the possessor of a mind only partially disciplined, as it is only partially informed. He may not easily perceive his deficient discipline, but in after-life he must often have cause to regret his deficient information. Nor is he whose mind is inordinately stored with scientific details one whit better off. Facts in education ought to be strictly subordinated to principles. A sound principle of science clearly understood will embrace a great multitude of facts, just as a simple rule of arithmetic will enable us to obtain a thousand products, each of which we should have to remember were it not for the rule. And in other branches of science, if the triumph of principle be not so apparent, it is only because we have a less accurate knowledge of its fundamental laws. It would be difficult indeed to say how many of the failures in the various walks of life are due to the neglect or ignorance of some principle which has either been omitted or dismissed from our calculations. From our leaders downwards we are a nation systematically ignoring principles, and in the minds of many a high esteem for fact is held to be quite consistent with a contempt for theory. A theory is not regarded as the very sap and life-blood of the tree of knowledge, but rather as the mildew that blights its leaves, or the worm that gnaws its root. Facts and theories are esteemed by this class of men to be sworn foes to each other, and the philosopher is supposed to live in a world of his own, rather hostile than otherwise to the world around him.

The existence of the two extreme educational theories to which I have alluded would thus seem to indicate the wisdom of a middle course. We ought to start from a platform as comprehensive as possible. Literature and science ought to go

hand in hand in producing the well-trained and well-informed disciple. And while there ought to be a broad basis of instruction common to all, there should be raised upon this common basis several distinct departments, so that the student may have the opportunity of attaining proficiency in that of his choice.

Professor Stewart next touched upon the subject of energy.

If an egg be allowed to rest on its shorter axis it will remain stationary, and any attempt to alter its position will be resisted by the egg. But the case will be different if we succeed, as perhaps we may, in causing it to stand on its longer axis, for in this position the slightest force will cause it to topple over. In the first case the egg is in stable, but in the second case it is in unstable equilibrium.

If it stand upon its longer axis at the very edge of a table, we cannot tell whether the first slight breath of air will cause it to fall inwards upon the table or outwards over the table, to be dashed to pieces on the floor. It is a case where a very slight cause may determine a very considerable issue as far as energy is concerned. Whether the egg will retain its energy of position by falling on the table, or whether it will convert this into the energy of motion, and ultimately into heat, by falling upon the floor, is an issue that depends upon a cause too minute to come within the scope of our calculations.

Now we have two types of machines, and in one of these we take advantage of the principle of stability, while in the other we use the principle of instability. A clock is a very good instance of a machine of the first kind. When a good clock has been wound up, we are perfectly sure that at noon to-morrow both its hands will stand at twelve, and that its weight will have fallen through a distance which we can calculate with the utmost exactness, if we take the trouble, all its movements being capable of the most rigorous calculation. On the other hand, a mine that is about to be fired by means of an electric battery is a machine or combination in which advantage is taken of nature's unstable arrangements. The powder which is about to explode represents chemical instability, just as the egg on its longer axis represents mechanical instability. The slightest percussion, the smallest spark, will rouse the imprisoned giant which it contains into volcanic energy. This spark has to be sent from a distance by the galvanic battery, and to do this we must complete the circuit. We cause the two wires to approach each other until they are only a very small fraction of an inch apart, but the contact is not yet complete—another touch, so slight as to be imperceptible, and the current passes, the powder is ignited, the mine explodes, and the fortress is hurled into the air. In such machines, great results, great transmission of energy, are due to the most trivial disposing causes. It depends at last upon the smallest conceivable movement of the wires conveying the current whether or not the fortress is to perish.

Nature also employs these two varieties of mechanism. In the solar system we have a clock on a large scale, only very much more accurate than any time-piece we can produce. The movements of every planet in the solar system are susceptible of the most rigorous calculation, and we have only to point our telescope properly in order to tell to the fraction of a second when a given planet will cross the field of view.

But in the living forms with which this world is so plentifully endowed, we have machines which, viewed in their relation to matter, belong to the second order we have described. The object here is not regularity, but rather freedom of action. The motion of an animal is not like that of a planet—the latter yields to calculation, but the former defies it. Now it is probably somewhere in the mysterious brain chamber that the delicate directive touch is given which determines our movements, just as the slightest possible touch to the wire in the battery chamber explodes the distant mine. That mysterious thing we call life is not a bully who swaggers out into the open universe, upsetting the laws of energy in all directions, but rather a consummate strategist, who, sitting in his chamber before his wires, directs the movements of a great army.

While we are thus led to confine the directive action of life to the very boundary of the universe of energy, it must not, however, be supposed that we have solved the problem as to the nature of life. We have only driven the difficulty into a bor-

der land of thick darkness, into which the light of knowledge has not yet been able to penetrate. If there be truth in these statements, and if we see in a living being a machine in which great results are produced by an exceedingly small primeval impulse, are we not led to expect that the unstable forms of nature will here be largely made use of? We must not, therefore, be surprised that the materials of our bodily frames are eminently liable to decay, or that the very intensity of our life is to be measured by the rate of change taking place in the tissues of our bodies, so that possibly those parts which have during life the noblest and most delicate offices to perform, are the very first to perish when life is extinct.

But this unstable matter, which is so wonderfully worked into our frames, is derived from the food we eat. This food does two things for us: it gives us energy in the first place, and in the second it furnishes our frames with a quantity of delicately organized tissue. But food is ultimately derived from the vegetable kingdom, and that kingdom derives it from the sun, so that we are led to regard our luminary as the ultimate material source not only of our energy, but also of our delicacy of construction.

To come now to our own luminary—very remarkable strides have lately been made in our knowledge of its physical constitution. It is difficult to say when and by whom the existence of sun spots was first remarked. Galileo, however, was the first to use them as the means of determining the elements of the sun's rotation. Besides these black spots on the sun's surface, equally mysterious forms have been seen to surround the sun on the various occasions of a total eclipse; these generally went by the name of red flames or red protuberances. Mr. Warren De La Rue was the first to prove that these phenomena were attached to the sun himself, and that the only office of the moon during an eclipse was to subdue the general light sufficiently to render them visible to the eye. While the red flames thus became objects of cosmical interest, Schwabe in Germany, and Carrington in this country, had both done much to increase our knowledge of sun spots. Schwabe, by a patient course of forty years' observations, had proved the existence of a well-marked periodical fluctuation in the amount and frequency of sun spots, the period of which was about eleven years. Carrington, again, had shown that the region of spots was a somewhat limited one, extending to about 20 or 30 deg. on either side of the solar equator, so that a spot never appears at the sun's pole, and he had also detected a proper motion of spots. Schwabe and Carrington had, however, confined themselves to mapping down accurately what they saw; but De La Bue, by the introduction of celestial photography, was enabled to obtain autographs of the sun which might be studied at leisure with an absolute certainty of their being correct. A large number of such pictures has been already obtained, and they are in the process of examination by Mr. De La Rue, and those associated with him in this research.

Some of the preliminary results of this examination have already been published, and they seem to point to a connection between the behavior and frequency of sun spots and the positions of the chief planets of the system.

Our acquaintance with the red flames has extended as rapidly as our knowledge of sun spots. It was discovered independently by Janssen and Lockyer, that these strange protuberances yield to the spectroscope under ordinary conditions of the sun, and without the necessity of waiting for a total eclipse. They exist in fact, always round the sun, but their brightness is quenched in the diffused light which surrounds the sun's border. When, however, we apply a sufficiently powerful spectroscope, the diffused light—consisting of ordinary sun light, and therefore containing a great variety of rays—is drawn out into a long spectral ribbon, and has its brightness scattered or diffused over the various parts of this ribbon, while on the other hand the light from the red flames, consisting only of one or two kinds, appears in the spectroscope as one or two bright lines not having their intensity weakened by the scattering action of the spectroscope. They, therefore, stand out in the field of view, while the ordinary light disappears. Lockyer has found, by this means, that there is an envelope of incandescent hydrogen surrounding the glowing surface of the sun, into which there are frequent injections of heated matter from beneath, and

in which there are violent hurricanes often moving at the rate of 100 miles a second. By the laboratory labors of Frankland and Lockyer, taken in connection with the solar observations of the latter, there is, I think, a probability of our ultimately ascertaining the pressure and the temperature as well as the chemical composition of the atmosphere of our luminary.

Descending now from the celestial bodies to our own earth, there is some reason to suppose that we are knit to our luminary, and possibly through him to the other members of our system by some other bond, besides that usually recognized. General Sir E. Sabine appears to have proved that disturbances of the earth's magnetism take place most frequently in those years in which there are most sun spots. This is confirmed by the experience of the present year, during which we have had a great number of sun spots, and frequent and large disturbances of the earth's magnetism.

I have already alluded to a possible connection between the behavior of sun spots and the positions of the planets; to which we may add that Schwabe and other observers imagine that they have discovered traces of a periodical variation in the appearance of the planet Jupiter. All the observations would appear to indicate the existence of some unknown bond between the different members of the solar system.

But that department of cosmical physics which is of most immediate interest to ourselves, is undoubtedly the meteorology of our globe; and here it is of great importance to know whether the earth's climate and atmosphere are influenced in any way by the changes taking place in the atmosphere of the sun. Such a connection has not yet been traced, but it has hardly yet been sought for in a proper manner. Recent observations discussed by Baxendell lead us to think there may be some connection between the daily changes in the earth's magnetism and the daily motions of the air. Coupling this with the fact that the frequency of terrestrial magnetic disturbances would appear to be connected with that of sun spots, we are led to contemplate at least the possibility of some connection between meteorology and sun spots.

If these remarks are of any value, they tend to indicate the probable union of the various branches of observational inquiry into one great cosmical research, and point to the wisdom of a very close union between the workers in the cognate fields of meteorology, terrestrial magnetism, and celestial physics.

At the present moment the prospects of meteorology are more hopeless than those of the other two branches. Our knowledge of the motions of the various components of the earth's atmosphere is extremely limited, and yet without this knowledge it is impossible to connect meteorology with the other branches of cosmical inquiry. If we endeavor to analyze the causes of this backward state of meteorological research, the first and most apparent is the magnitude of the problem. We are too intimately associated with the earth and its atmosphere to be easily able to tell its motions. Strange to say, the meteorology of the sun is more easily studied than that of the earth, and we know already as much about the strength of solar storms as we do about that of terrestrial hurricanes.

But another cause of the backward state of Physical Meteorology arises from the fact that there are two branches of science, each of which may be furthered by meteorological observations. There is first the physiological branch of meteorology, the object of which is to trace the influence of climate upon animal and vegetable life; and there is next the physical branch, the object of which is to study the physics of the earth's surface, and more especially the motions of its atmosphere.

It is now high time that a separation should be made in the mind of the observer between these two branches of research. If he would rather pursue the physiological inquiry, let him say so definitely, but if he wish to pursue physical meteorology, let him clearly keep before his mind the object of all his labors. He should ask himself the question, what is the best system of observation, and what is the best method of reduction, to advance the great object of physical meteorology—a knowledge of the motions of the earth's atmosphere, and of the causes thereof? He should not fix upon a system of observations and a method of reduction that may possibly, but upon one that must necessarily, further this great object.

I have thus endeavored in a few words to bring before you the recent advances in cosmical physics. Besides this, there are two other no less important branches of physical inquiry. We have the physics of organized beings, and we have also molecular physics. But there is this difference between these two branches and that of which I have now spoken:—To forward physiology or molecular physics we chiefly require experiment, but to forward cosmical physics we chiefly require observation. You are all aware that at the present moment a Royal Commission is inquiring as to the relation between Science and the State; and perhaps, therefore, you will permit me the opportunity of stating my views as to the manner in which this very necessary assistance may best be given. I think that those branches of science which demand for their extension experiments not requiring very great time, may be furthered with much advantage in institutions such as Owens College. I believe it to be advantageous to bring the highest class of physical teaching into contact with research. If Government be disposed to grant pecuniary aid to such researches, an extension of the allowance made annually to the Government Grant Committee of the Royal Society would appear to be a very legitimate way of accomplishing this object.

The scientific professors of a college would thus have to state the aim of their research to a committee of the Royal Society intrusted with the disposal of Government means, and the requisite funds would be forthcoming. No one, I think, can doubt that the small sum of £1,000 annually intrusted by Government to the Royal Society for miscellaneous experiments, is administered in a most praiseworthy manner; and if Government would be ready to grant, and the Royal Society willing to undertake, an extension of this trust, it would, I think, be a great point gained for this class of physical experiments. (I speak only of experiments, but the encouragement of experimenters is a point of equal importance.) But when we come to experiments and observations requiring great time, the case is very different. Certain experiments, whether from the great time they require, or the great expense they demand, cannot be well performed in a college; while routine and long-continued observations such as those connected with the various branches of cosmical physics, are of such a nature as to require a central establishment to superintend their organization and reduction. There is thus, I think, the necessity for a central establishment of some kind devoted to that class of experiments and observations requiring great time, great space, and great expense for their completion.

Referring more particularly to Cosmical Physics, I feel convinced that meteorology should be pursued in connection with terrestrial magnetism and solar observations; and were a well-considered scheme for solving this great problem fairly introduced, I am sure that scientific institutions and individuals throughout the country would do all that they possibly could to promote this most important branch of physical research.

THE CAUSES OF RAILWAY AXLE FRACTURE, AND THE REMEDY.

BY W. BRIDGES ADAMS.

From "The Journal of the Society of Arts."

The fatal accident which has slain so many persons, and maimed so many more, perhaps for life, and the impossibility of ascribing blame for its occurrence to any individual or corporate body, leads us to the inquiry as to the possibility of future precaution. The contingency of one train damaging another at the moment of passing each other on two lines of rails seems at first a remote one, but of course the chances in favor of it will be on the increase with the increase of traffic, and it is therefore worth analysis.

That the breakage of the axle was caused by a gradual deterioration of material, may be assumed *a priori*, for the wagon, so far as we know, was one long in use, originally constructed to carry 6 tons, and loaded with less than that amount when the axle suddenly broke.

WHEELS AND AXLES.

In discussing the question of wheels and axles, we must first define them, for there are wheels proper, and wheels so-called, which are not wheels at all, but only rollers. In its principle, what is called in railway parlance an axle and pair of wheels is, in truth, only a garden roller with the centre portion cut away. If any one tries to pull a garden roller round in a small circle, he will soon find himself in the difficulty that it is a sledge, and not a rolling body, that he is working at. The garden roller is a revolving axle, with the wheel fixed fast on it, and so is the railway axle. Some long time back, an agricultural machine maker patented and made what he called a clod crusher. It was a revolving harrow, some 7 ft. in length, set all over with spikes. But no power of horses could draw it, save in a straight line. To change its course was impracticable, because both ends would persist in travelling at the same rate of speed, a practice strictly in conformity with geometry. So our would-be clod-compeller was compelled by the clods to change his practice. He divided his roller into two separate wheels, each being enabled to revolve separately on the axle. Still, each wheel was so broad that he gained little advantage. He then subdivided it into four wheels, and it was much more easily managed, and he carried on the subdivision till he had reduced his rollers to the width of ordinary wheels, all strung on one axle together. In fact, he had gone through once more all the original contrivances which had in past ages developed wheels out of a roller, and this is precisely the process to which railway mechanicans must, sooner or later, address themselves. They must take to wheels proper, and eschew garden rollers, however cunningly they may cut and carve them into fanciful forms, conical or other, for it is a law of nature that, to avoid friction, wheels must travel at differing rates of speed along pathways of differing lengths.

It is recorded that when Donald Macdonald first descended from the Highlands and beheld a four-wheel carriage travelling along with a Lowland Earl, he first stared with astonishment, and then burst into a fit of laughter, exclaiming, "Weel rinnit, wee wheel, big ane canna catch ye," not realizing the fact that the big wheel made fewer revolutions.

It is quite true that by making, in railway practice, each half of the garden-roller the frustrum of a cone, it is possible so to vary the diameters as to be the equivalent to separate wheels, provided sufficient end-long movement of the axle be arranged. But this only holds good as regards a single axle, and vehicles with a single axle are not prevalent on railways; they have never less than two, and sometimes more. The frames to which these axles are attached are oblong, and the axles are supposed to be rectangular to the frame, and parallel with each other, the line of traction being parallel with the planes of the so-called wheels. So arranged, they are adapted to run truly on straight lines of rails. But such straight lines are purely imaginary. Rails are a succession of large and small curves and zigzags, on which the coned rollers incessantly vary their tread, and oscillate from side to side, on sinuous courses, like so many snakes, but not so gracefully. In this oscillating movement the rollers are seeking the path of least friction; and so well is this understood by the engine-drivers that the trains of wagons are coupled only by loose chains or links, for the simple reason that, were they close-coupled together, the friction of the treads and flanges against the rails would be so great that it would be impossible to haul them along. With passenger trains this sinuous motion is so annoying that, perforce, the train is coupled close together to check it, and the wheels or rollers tell the story of the additional friction they thus have to encounter, by the amount of frictional vibration and retardation thence ensuing. And frequently at stations the driver will take the opportunity to loosen the couplings, in order to ease his engine.

LONGITUDINAL SHOCKS.

Longitudinal shocks of more or less intensity, occur in all trains, whether in drawing or propelling, and if the traction and buffing springs be insufficient in elastic power, the frames, especially on curves, are apt to get a diagonal set. In wagons without traction springs or buffing springs, the haulage, by loose couplings, is a succession of violent jerks, frequently breaking the couplings and causing accidents.

And again, when the buffers on one side get violent blows on curves, the oblong frame becomes rhomboidal, and though the axles retain their parallelism with each other, they cease to be rectangular to the line of traction, and the wheels remain at a permanent tangent with the rails. In this position the strain upon the axle, by the pressure of the wheel flanges against the rails, becomes enormous, and the longer the wheel base the more mischievous it is.

HAULAGE RESISTANCE.

It may be taken as an axiom that resistance to haulage—apart from gravitation on inclines—is the measure of axle strain in torsion. The normal resistance is assumed to be 8 lbs. per ton of load on the axles, on the level. If, then, we find, as sometimes occurs, that trains of wagons will not run down inclines of 1 in 72 without haulage, we may be sure that there is something vicious in the structure, whether original or induced by violence. Curves and bad permanent way will quadruple the resistance to traction, and practically the resistance in being obliged to shunt a train into a sharp-curved siding will reduce the train by one-third to one-half of what the engine is able to deal with on a straight line.

AXLE TORSION.

Under these circumstances, the railway axle is exposed to great torsional strain, with a condition more trying than that of the fixed axles on the common road. The common road axle being a fixture, if it be weak for its load, any bending is only in one direction, viz., upwards at the ends. If the revolving axle bends under the load, it bends in every direction radial to the centre in a constant succession of changes. The bending, of course takes place in the weakest part, where it is reduced for the bearing, or for the boss of the wheel. If it bends at all under the load, aggravated by eccentricity of movement, the final breakage is only a question of time. The commencement is by a fine circular line round the weak part, so fine as to be undiscernible by the naked eye. This line gradually deepens to a sixteenth of an inch, half an inch, and so on till the central portion becomes too weak to hold it together and it drops apart. Breakage of axles in this mode is not uncommon, and those who have locomotive engines in charge, with cranked axles, maintain that the access of oil in the opening crack acts as a wedge to quicken the fracture, and the question of duration is a known quantity. In truth, the crank axle of an engine is a very weak axle. Its diameter is usually the same as that of straight axles, while its length, if straightened out in the cranks, will be found to be double that of the straight axle.

BREAKING STRAIN.

It will be seen, then, that the cause of the breakage of railway axles is to be found in the fact that they are strained beyond their powers, not by the load, but by imperfect structure of the vehicle they are attached to—imperfect, possibly, originally, but commonly by violence in use. The running is "wringing the neck of the axle."

With a view to lessen lateral friction of the wheel flanges as much as possible, it has been customary to keep the axles as near as possible together. This, if the bodies be long, involves "hogging," and oscillation, with a bad distribution of the load. Other things being equal, the nearer the axles are to the wagon end, the steadier they will be; but then flange friction increases with the length of wheel base, and a remedy must be provided for this.

Supposing that a train of wagons were built perfectly true at the outset, for a straight line, the multitude of longitudinal shocks would soon set the wheels out of truth, and so the question arises, whether it be possible so to construct them that diagonal shocks to the frame, giving a permanent set, shall not affect the true running of the wheels; and next, whether wagons may not be so constructed as to dispense with the loose coupling, which is a material source of breakage to couplings, and displacement of the wagon frames. We think it is. Desirable as it is to point out the causes of the defects, it is still more useful to point out the remedy.

EXISTING STRUCTURE OF VEHICLES.

The existing mode of construction is, to fix to the sides or sole bars of the wagon four iron forks called horn-plates, up and down which the axle boxes slide vertically with the movement of the bearing springs, similar to the row-locks of a boat which

hold the oars. The fit of these horn-plates in the grooves of the boxes must, of course, be a loose one, or they could not work equally. Consequently, every blow which disturbs the frame carries the horn plates with it, and sets the wheels and axles askew.

IMPROVED STRUCTURE.

The horn-plates are dispensed with, and, instead of them, axle-guards are made to clip the two axle-boxes firmly, and bend round the wheels horizontally, and form a central pivot-hole 7 in. within each axle. A strong pivot is forged on a plate turning up at the ends, and bolted between the two diagonal timbers of the wagon frame at each end. The axle-guard frame thus forms a caster-pivot, which carries no load, but merely acts as a guide or eccentric centre for the wheels. The bearing-springs are fixed on the axle-boxes above the axle-guards, and carry the load by long pendant round rods, with ball and socket heads and nuts passing through strong iron brackets fixed to the sole bars. Thus there is perfect free movement for the axles to move laterally and radially on irregular rails, or when the wheel-flanges press against the outer rails on a curve—when the axles take a true radial position pointing to the centre of the curve, each independently of the other. If any distortion happens to the frame by a blow, making it rhomboidal, it does not affect the relative position of the two pivots, and the wheels will run as true with a distorted rhomboidal frame as with a true oblong; and on a straight line the gravitation of the spring shackles insures a rectangular position.

And this free movement of the wheels from side to side, while preventing all jamming of the flanges, will permit the close coupling of the trains without affecting the wheel action, and thus reduce the longitudinal shocks to the minimum. Thus the wagon bodies may form a series of tangents on a curve, free from oscillation. The buffers are curvilinear to give free action. It will be seen that the short distance between the axle centre and the axle-guard centre, while keeping the wheels true on curves, also keeps the wheels true to the gauge, and free from oscillation. The wagon is adapted to carry 10 tons of coals or minerals quite steadily at any speed. The spring-plates are 6 in. broad, and thoroughly elastic. The cubic contents are 381 ft., and sliding iron bars are made to clip the upper edges, permitting loading without trouble, and holding the light top sides together.

COAL WAGONS DIRECT FROM THE PIT'S MOUTH TO THE CONSUMERS' PREMISES WITHOUT CHANGE.

On this system, the cones of the wheels or rollers may be brought into effectual play, widening the gauge of the rails where the curves are very sharp, thus enabling coal wagons of 12 ft. wheel base and 20 ft. length to go direct to the pit's mouth round curves of one cha n radius. Such wagons also will permit the delivery of coal direct from the pit's mouth on to the consumers' premises, such as large gas-works, running on the wheel flanges, on channel rails laid on the streets and roads as tramways, as shown on the diagram. It is true that very sharp curves would involve tread friction, as may be any day seen in street-tramway working, but this can be very easily provided for, and then the movement becomes perfect, and the friction on the channel rails would be less than that on the railway proper, as the flanges would cease to rub.

It is thus possible to get rid of the contingency of railway axles breaking by unfair wear, when otherwise faultless. And when we get to the proper process of forming hollow axles, we shall have far less chance of flaws. And if coal and goods wagons be thus constructed, they may run at as great speed, and with more safety, than existing passenger trains. The cost and consumption of fuel is mainly governed by the resistance to haulage.

EVIDENCE ON INQUEST

The intelligent evidence given by Mr. Sacré and Captain Tyler made the matter very clear:—"The wagon was estimated to carry a load of 6 tons, and the dead-weight of the wagon, unloaded, was 2 tons 5 cwt, and it had been in use 18 years." This was a satisfactory and economical proportion, of ample weight for strength, without the surplus dead-weight we have heard so much of lately. Captain Tyler said, "the flaw was round the whole circumference of the axle-tree.

The flaw was not due to the quality of the iron, but arose from wear and tear. A large portion of the section of the axle had been defective, and it was only a moderate-sized piece in the middle that held on. As the truck worked, the sound portion got smaller, and at last it got so small that it failed altogether."

This is preeisely the process of breakage in all railway axles subjected to a bending strain, either by overloading, or by torsion on sharp curves, or by vicious or damaged structure.

In the running of ordinary trains, the tendency is for the leading wheels to hug t e outer rail with their flanges where the lines are curved, and the result of this is to throw the trailing-wheels against the inner rail, placing the vehicle in a partly diagonal position, with an incessant sledging, frictional grind, inducing the "wear and tear" to which Captain Tyler alludes. If the wheels were free, instead of being held fast laterally to the frame, they would find out for themselves the path of least friction; the torsion of the axles would cease, and oscillation of the bodies would disappear also. And be it remembered that the tendency to hug the rail with the wheel flange with rigid pressure is the main cause of "getting off the line."

Mr. Patrick Stirling, the engineer of the Great Northern Railway, and than whom no more competent engineer exists, said: "It is quite possible the flaw in the broken axle might have been an incipient one at the time of its original construction, but not perceptible to the eye. A concussion with another wagon might have completed the break of the axle in question. There is a considerable curve in the locality of the accident. A curve always brings a greater strain on the axle than a straight line."

CRANKED AXLES.

In February, 1869, a paper was read on the Mauritius Railway, at the Institution of Civil Engineers, and, in the course of the discussion on locomotive engines, Mr. Harrison, the Engineer of the North-Eastern Company, made the following remarks: "Mr. Adams had stated that he could make an engine which would pass round curves of three chains radius. He knew that gentleman's radial motion had been successfully applied to engines and carriages, and he had no doubt that Mr. Adams was going in the right direction in designing stock for traversing sharp curves, but still he thought it would be much better, if possible, to avoid sharp curves, and thus remove the necessity for adopting these means of working. It was only when the curves were exceedingly sharp that it was necessary to resort to these expedients. There was no stronger argument against very sharp curves than the comparative wear of crank axles on curves and on straight lines, and he could state from experience that a crank axle in an engine working on straight lines would last at least six times longer than the crank axle of an engine working over exceedingly sharp curves."

Jeremy Bentham was accustomed to remark that "it would be a great mechanical convenience if the surface of the world were all down-hill; but that as it was not so, he must put up with it." And even so we must deal with our railways. Let us by all means get straight lines when we can; and it would be better, on the whole, to make straight lines in given lengths, connected by sharp curves at intervals, than to form them in general curves; only, in such case, we must take care that our moving stock be adapted to work the curves; and, in any case, our wheels and axles should be so constructed as to have free rolling movement under all circumstances, and never be subjected to other strains than that of the direct load borne upon them. With regard to crank axles, there is no apparent reason why they should exist at all, other than a superstition. Straightened out in the cranks, they measure twice the length between the wheels that straight axles do, and yet, strange to say, they have no increase in diameter. The steadiest, fastest, and most powerful locomotive engine now existing on any English line has been produced by Mr. Stirling, and it has a straight driving axle and outside cylinders. It could scarcely exist at all for any useful purpose with a crank axle; and, with requisite appliances, it could, no doubt, work with coupled drivers and increased power.

SUMMARY.

The faults and accidents are not in individuals but in the system of all large establishments, whether government or other, that sticks to red tape and eschews

progress, that would build every locomotive and wagon to an antique pattern, in order to save trouble in organization, as though the works of man were as perfect in their beginning as the works of the Creator; as though there were not construction, destruction, and reconstruction in nature itself. But for the competition of individuals, we should still be travelling in stage-coaches drawn by horses, and building wooden war-ships, till the world were denuded of its forests. Not for this were our iron and coal stored in the underground cellars of nature!

RESISTANCE TO TRACTION.

Translated from "Weisbach's Mechanik der Zwischen" und "Arbeitsmaschinen."

According to numerous experiments made by Morin, the resistance of a good concrete or macadamized road to the motion of a wagon is—

(1.) Nearly in direct proportion to the load.

(2.) Inversely proportional to the height of the wheel.

(3.) Nearly independent of the number of wheels and of the breadth of tire.

On soft or yielding roadway, or upon a road just macadamized, the resistance diminishes with the breadth of the wheel. For slow motion, the resistance is independent, or nearly so, of the velocity; and it is as great for wagons with springs as for those without. If the motion is rapid the resistance increases, being nearly proportional to the velocity; it is less if the wagon has springs. The traction in this case diminishes with both elasticity of road and elasticity of vehicle.

MEAN DIAMETER.	Freight Wagons.		Carts.		Coaches.	
	4	4½	5	6⅔	3⅔	3⅔
					Walk.	Trot.
I. BROKEN STONE.						
1. In good condition, dry and smooth	1/60	1/68	1/66	1/85	1/48	1/41
2. Somewhat damp, dusty, and with scattering stones.	1/35	1/41	1/47	1/59	1/34	1/27
3. Very hard, coarse stones, wet	1/43	1/50	1/57	1/71	1/42	1/27
4. Hard, shallow tracks in soft surface coat	1/27	1/32	1/30	1/46	1/26	1/22
5. Hard, tracks	1/22	1/26	1/30	1/37	1/21	1/18
6. Much travelled, thick coat of mud	1/19	1/22	1/25	1/31	1/18	1/16
7. Cut up, tracks 2 to 3 in. deep	1/14	1/17	1/19	1/24	1/14	1/12
8. Very bad, thick coat, bottom hard, tracks 3 to 4 in. deep	1/13	1/16	1/17	1/21	1/12	1/10
II. CONCRETE.						
1. Very good	1/65	1/75	1/86	1/108	1/62	1/42
2. Ordinary, dry	1/60	1/70	1/80	1/100	1/57	1/41
3. Ordinary, wet and coated	1/46	1/54	1/74	1/76	1/44	1/33
III. WOODEN ROADWAY OF A BRIDGE.	1/43	1/50	1/59	1/71	1/41	1/41
IV. DIRT ROAD.						
1. Very good and dry	1/27	1/32	1/36	1/46	1/26	1/26
2. Gravelled 1 to 1⅔ in. deep	1/10	1/12	1/14	1/17	1/10	1/10
3. Gravelled 2 to 3½ in. deep	1/9	1/10	1/12	1/15	1/9	1/9
4. Gravelled 4 to 5½ in. deep	1/8	1/10	1/11	1/14	1/8	1/8
V. UNBROKEN SNOW.	1/14	1/17	1/19	1/24	1/14	1/14

A breadth of tire of 4 @ 4½ in. is most advantageous, as narrower wheels cut the road, and power is not economized by the use of wider.

Theory shows the traction to be proportional to $\left(\frac{L^4}{b\,r^2}\right)^{\frac{1}{3}}$; *i. e.*, it is directly as the cube root of the 4th power of the load, and inversely as the product of the breadth and the square of the radius. This does

not correspond with the empirical results mentioned above. We have $(L^4)^{\frac{1}{3}} = L(L)^{\frac{1}{3}}$; $(r^2)^{\frac{1}{3}} = \left(\frac{1}{r}\right)^{\frac{1}{3}}$. r and $(1.1)^{\frac{1}{3}} = 1.032$.

Hence if the values of L, r, and b vary within narrow limits, differing from a mean value by not more than 10 per cent. we may, instead of 1.032, substitute 1, and instead of $(L)^{\frac{1}{3}}$, $(r)^{\frac{1}{3}}$ and $(b)^{\frac{1}{2}}$ make use of constant mean values. We should then have, with Morin, the traction directly proportional to the load, and inversely to the radius, and independent of the breadth of tire. This receives further confirmation from the fact that resistance is also proportional to the friction of the axles as well as to concussions; and that when these conditions are introduced into the theoretical problem the resulting proportions agree with those deduced from experiments.

The preceding Table contains co-efficients of resistance under the conditions specified. In order to find the force, P, necessary to draw the load L, the total weight of load and wagon must be found, and this sum must be multiplied by the coefficient. If the road rises, the result must be increased by the product of the result thus obtained by the sine of the angle of elevation.

FRICTION.

From "The Iron Age."

When a body is pressed upon the surface of another, it is moved along that surface with difficulty. If you attempt to cause one of the surfaces to slide on the other, a certain force opposes itself to the effort, which is found to become greater as they are pressed together with greater force. By rendering the surfaces of contact more smooth, or by interposing unguents between them, the amount of this resistance, called friction, may be greatly diminished, but it never can be altogether dispensed with. The principal experiments which have been made upon friction have reference: First, to the proportion in which the friction increases with the pressure of the same surface. Secondly, to the variation of the amount of friction produced by the same pressure upon equal surfaces of different substances. Thirdly, to its relation to the size of the surface of contact, the pressure being the same; to the influence of the time during which the bodies have been in contact on the amount of the friction; and, especially, to the distraction between the friction which resists the first motion of a body from rest, and that which opposes itself to its motion during the continuance of that motion; and we quote from the best experiments on the subject made by Coulombe, Prof. Vince, Mr. Rennie, and M. A. Morin. It has been clearly demonstrated by these scientific gentlemen, that the friction is always proportionate to the pressure; for if the surface of one body be pressed upon that of another with a certain force, and if that be doubled, the friction will be doubled; if the force be increased three times, the friction will be tripled, and so on; and from the tables here attached, the following may be mentioned as general conclusions :—

First.—That the ratio of the friction to the pressure in all hard metals, for pressures less than 32 lbs. on the square inch, is nearly the same, and for these metals the friction varies one-sixth the pressure. *Second.*—That the friction of soft metals is very much greater than that of hard ones. *Third.*—That the same relation exists in respect to the frictions of soft and hard wood: two surfaces of pine being pressed together, exhibited a friction equal to more than one-third pressure, while the friction of the surfaces of teak or oak was scarcely more than one-ninth pressure. Whether the fibres of the two surfaces of wood be parallel or perpendicular materially affects the amount of friction, and whether they be wet or dry. Of oak on oak, fibres being parallel, the ratio of friction to the pressure was from 60 to 65; when the fibres were perpendicular, the ratio was 51 ; when the surfaces were wetted, it rose to 71. It is a practical fact, that friction is considerably augmented in the surfaces of wood by wetting them.

Friction is less between surfaces of dif-

ferent kinds than between those of the same kind, and two metals of the same hardness should never move on one another, though Leslie asserts steel to be an exception; but recent experiments prove that fine brass moving on a steel journal has considerably less friction than steel on steel, and consuming less oil *pro rata* of load. Friction is greater at the first moving of the load than when fairly in motion, and it is asserted, in regard to different degrees of velocity over a certain space, that, as a general rule, the friction is the same for all velocities.

The amount of friction is independent of the extent of the surface pressed, provided the whole amount of the pressure remains the same, and that the extent of the surface pressed is the same. By increasing the surface which supports the pressure, you diminish the amount of pressure upon every point of it, and thus you diminish the friction on every point; although there are more points which rub, their aggregate amount of friction is only the same as before.

The friction of a body, when in a state of continuous motion, bears a constant ratio to the pressure upon it, which is the same whatever may be the velocity of the motion. This fact was clearly proved by M. Morin, by extensive experiments under order of the French Government.

The general effect of unguents upon friction is materially to diminish it; but it is important to state, however, that they entirely destroy the constant ratio which, without unguents, friction is found to bear to the pressure. Thus, Mr. Rennie found that the friction of an axle of yellow brass upon a collar of cast iron was, without lubrication, in every case $\frac{1}{4}$ the pressure ; when the surfaces were oiled this ratio became, under a pressure of $\frac{1}{2}$ cwt., only $\frac{1}{37}$, but when increased to 11 cwt. it rose to $\frac{1}{6}$. Axles of brass, made of copper and tin, moving in cast-iron journals, exhibit, when lubricated, the least amount of friction, and the best lubricator appears to be clean tallow. With this unguent the mean results of Rennie's experiment show, for a pressure of 1 to 5 cwt., a friction of $\frac{1}{39}$ the pressure. It is still a more remarkable fact that the softer lubricators, as whale oils, hog's lard, sweet oil, etc., increase the ratio of the friction to the pressure, while harder lubricators, as soft soap, tallow, and carefully made anti-friction metals, greatly diminish it. The latter compound should be made of sufficient hardness to attain a high polish in the journal box from running on the journal; it should not be porous, but close-grained and fine in its crystallization, and not melt under a temperature of 700 to 900 deg., at which heat it should run free and clean into the mould or bearing; when cut with a chisel, by a blow from a hammer, it is tough, yet flying before the cutting edge of the tool; it will not fill the teeth of a file when brought in contact with it, but fall away in finely separated particles. We recommend its use in all machinery, particularly where high speed is obtained, or where the journals are likely to heat. It has been of the greatest advantage over a solid iron or brass bearing, from the fact that it will run with less friction, without oil; and even when heated so as to melt, it will do no injury or cutting to its running journal.

In the manufacture of these metals for anti-friction purposes, the author of this article has, by numerous experiments, tried to achieve the desired end, and is now offering to the mechanical community metals equalled by none for their anti-friction qualities. To produce metals that shall give the least friction to the greatest pressures, at certain required speeds, with or without lubricating compounds, and also making them wear, with ordinary care and mechanical management, equal to the best metals known in every respect. We regret to see some of our mechanics still insist upon using the lower and cheaper grades of Babbitt or anti-friction metal in their journal bearings. From long experience in machinery, we can distinctly assert there is no economy in its use, but sooner or later a constant source of annoyance to the purchasers of the machinery, and often the cause of their losing much time and trade in business. We, therefore, recommend all builders of engines and general machinists to buy a good article; resting assured that a good and reliable-wearing anti-friction metal cannot be made and sold at the low figures now offered in the market. A composition known to consist of a few parts of antimony to a large proportion of lead, with, perhaps, a trace of copper, cannot be called an anti-friction metal; but, from its soft, fibrous qualities, is just the reverse, and creates the very agent we, in a meas-

ure, wish to destroy. Many years' experience as an engineer, and a worker among machinery of various kinds, enables us to assert that too little attention is paid to those parts of moving machinery requiring special lightness and care in their construction, that the friction may be diminished; and probably no parts are more neglected than the journals, which, instead of having as much surface as possible, are often reduced to absurd dimensions, causing trouble in the machinery, annoyance to the engineer, and an ill-reputation to the engine-builders and to the material of which journal boxes are made of or packed with. Instead of anxiously caring for these important moving parts, giving them the best materials in construction, and the best lubricators, they are too often supplied with inferior workmanship and metals, and the result is an early destruction of the machine. And often at such times it is no uncommon practice among persons having charge of heavy or fast moving machines to keep a constant stream of cold water running upon the

Surfaces of Contact.	Friction of Motion. Coefficient of Friction	Friction of Quiescence. Coefficient of Friction.	Unguents.
Oak on oak, fibres parallel	0.075	0.164	Tallow.
Oak on oak, fibres parallel	0.067	0 067	Hog's lard.
Oak on oak, fibres perpendicular	0.083	0.254	Tallow.
Oak on oak, fibres perpendicular	0.072	0 254	Hog's lard.
Oak on oak, fibres perpendicular	0.250	0.254	Water.
Oak on cast iron, fibres parallel	0 080	....	Tallow.
Oak on wt. iron, fibres parallel	0.098	....	Tallow.
Wt. iron on oak, fibres parallel	0.256	0.649	Greased and saturated.
Wt. iron on cast iron	0.103	....	Tallow.
Wt. iron on cast iron	0.076	....	Lard.
Wt. iron on cast iron	0.070	0.100	Olive oil.
Wt. iron on wt. iron	0.082	....	Tallow.
Wt. iron on wt. iron	0.081	....	Lard.
Wt. iron on wt. iron	0.070	0.115	Olive oil.
Wt. iron on brass	0 063	....	Tallow.
Wt. iron on brass	0.075	....	Lard.
Wt. iron on brass	0.078	....	Olive oil.
Cast iron on oak	0.189	....	Dry soap.
Cast iron on wt. iron	0.993	0.100	Tallow.
Cast iron on cast iron	0.314	....	Water.
Cast iron on cast iron	0.100	0.100	Tallow.
Cast iron on cast iron	0.070	0.100	Lard.
Cast iron on cast iron	0.064	——	Olive Oil.
Cast iron on brass	0.060	0.106	"
Brass on cast iron	0.077	....	"
Brass on wt. iron	0 061	....	Tallow.
Brass on wt. iron	0 072	....	Olive oil.
Brass on brass	0.068	0.108	"
Steel on cast iron	0.079	....	"
Steel on wt. iron	0.076	....	"
Steel on brass	0.053	....	"
Steel on brass	0.067	....	Oil and plumbago.

FRICTIONS OF AXLES IN MOTION.

	Lubricator properly supplied.	Lubricator continually flowing.
Brass on brass	0 079	.....
Brass on cast iron	0.072	0.049
Brass on wt. iron	0.073	.....
Wt. iron on brass	0.075	0.054
Wt. iron on cast iron	0 075	0 054
Cast iron on cast iron	0.079	0 054
Cast iron on brass	0.075	0.054
Cast iron on hard woods	0.100	0.092

journals. W cannot condemn this in too strong language, and have yet to see the benefit accruing from it; nor do we see, in our experience, any benefit from the immoderate use of flour of sulphur, black lead, etc., to reduce the friction or the heat of the heated journals. Our experience has taught us differently; we would reduce the pressure of weight upon the journals, slow the speed of the machine, use plenty of tallow and no water; and our word for it, the friction will be lessened in the shortest space of time, and our journals kept bright and smooth. We give above, tables of various experiments of M. Morin, under the special patronage of the French Government; he divided them under the heads: I.—Experiments on friction without unguents. II.—Experiments on friction of unctuous surfaces; that is, where some lubricator had been used, and then the surface carefully wiped, so that no perceptible unguent interposed. III.—Experiments with unguents interposed. Of these three classes of experiments, as no machine is placed in operation without lubrication, we will content ourselves by giving some of the data of the principal bodies upon their surfaces of contact and lubricators used.

The effect lost by friction in axle and bearing is expressed simply by the formula:

$$\frac{P = \pi d W n}{12.60} \qquad \frac{f = W d n f}{230}$$

in which W=weight in pressure in the bearing; d=diameter on which the friction acts in inches; n=number of revolutions per minute; f=coefficient of friction in table. In ordinary machinery the coefficient may be assumed at 0.065, then

$$P = \frac{W d n}{3530} \text{ and horse-power} = H = \frac{W d n}{194150}$$

In conclusion, we quote from standard authorities these few simple facts: Coulombe states that friction of a sliding body equals 25 per cent. of the pressure, a revolving body 15 per cent., a rolling body 5 per cent. While Mr. Southern, in 65th volume "Philosophical Report," states that experiments made by him with a revolving body was 1-40th the weight, Mr. Wood found the friction of locomotive axles about 1-60th the weight, with ample lubrication with tallow, and greater with oils. Mr. George Rennie states that the friction of shafts, with a pressure of 1 to 5 cwt., is not more than 1-39th the pressure, with tallow lubricator and anti-friction metals interposed. Mr. Bourne, in his late treatise on the Steam Engine, writes and asserts, that where a composition metal is made of copper, tin, and antimony, a finer and more durable metal is presented for anti-friction purposes, and that the friction of surfaces was less in all revolving or sliding bodies; and, further, that the oils or unguents remained upon the surface longer, and the journals were less liable to heat. He too asserts that where the greatest pressure was, the hardest unguents were the best lubricators, and when the weight was lightest, oils, etc., were the best agents. With oils the friction appears to be the least when the pressure on the surface of a bearing is about 90 lbs. per sq. in.; but in every case, he adds, where the reduction of friction was an absolute necessity, the use of excellent anti-friction metals was a decided gain in power, a saving in machinery, and an economy of time, labor, and money.

A Railway "Traveller, Constructor, and Director," writes in the "Times:"—"Progress is rapid in these days, and railways have not attained perfection. New propelling powers will be discovered by the advancement of science, and I shall probably be set down as a wild enthusiast if I venture to prognosticate that in another generation our passenger carriages, instead of having their load placed above the centre of gravity, will be suspended below that centre by the elevation of the rails, by which accelerated speed will be obtained with greater safety than on the present system. But neither directors nor travellers are yet prepared for that sweeping but certain change. They are, however, I believe, prepared that we shall have a line for human beings, and another for luggage, upon our leading, and, I will add, generally well-conducted and well-managed lines. For the thought is not pleasant, that we may be burnt, as at Abergele, or precipitated down an embankment, as at Tamworth, by the blundering negligence of a careless pointsman."

The address of A. W. Humphreys, Esq., presented in this number, was carefully revised by the author for our pages.

SMALL IRON-CLAD SHIPS.

From "The Mechanics' Magazine."

At the late meeting of the British Association at Liverpool a paper was read by Mr. Michael Scott, C. E., N. A., upon a method of constructing ships-of-war of moderate dimensions. It is a relief to turn for a few moments from the sea-going turret ship controversy, and all the bitterness and obstinacy attaching thereto, to the consideration of something really practical and sensible in the way of iron plates, turrets, and big guns. Valuable suggestions or inventions are not always brought into the light of day with a flourish of trumpets, or under the patronage of the great and influential. There is such a thing as modest genius still in the world. If we are not greatly mistaken, the mechanical inventions which have from time to time been produced have generally made their appearance and made their way unaided by what is called the honor and intelligence of the country.

It would be easy for us to run back 50 or 60 years and prove the truth of this assertion, but it is unnecessary; the fact is too patent to require arguments or illustrations in proof thereof. The same principle which holds in philosophy, in morality, and in religion, holds in mechanics, viz., if a thing be true it will, sooner or later, make its way and be recognized. We have no hesitation in stating that we think highly of Mr. Scott's proposed arrangements for the building of war ships of moderate dimensions. In fact, there has been nothing so practical and efficient proposed since the building of the "Enterprise" and "Research." Since these two ships were built there has been no attempt on the part of our authorities to build small iron-clad ships. The Messrs. Laird built two small vessels—the "Wivern" and the "Scorpion"—which have proved utterly useless for the purpose for which they were intended. We believe that the true policy for the Admiralty to pursue now, is to build some small iron-clad ships to act in concert with the huge and heavy ships which constitute our fleet. We think that Mr. Scott's ship will fulfil the required conditions. At any rate, nothing better has yet been proposed, and we therefore advocate the adoption of his design. Mr. Scott's plan for a small ship-of-war is intended to compete with a "breastwork" monitor, as designed by Mr. E. J. Reed, C. B., late Chief Constructor of the Navy. The main object of Mr. Scott's plan is to reduce the amount of armor to the smallest possible extent, and so to dispose that which he must of necessity have, as to protect the vital parts of the ship. Mr. Scott believes in a high freeboard as being essential for rendering a ship seaworthy, and he also believes that a high freeboard is not incompatible with the turret system. To quote Mr. Scott's words, he has "designed a structure, to wreck even the non-vital parts of which would occupy the most powerful modern war ships so long a time that before their task could be accomplished they themselves might be sent to the bottom." Now this is what we have always advocated. The power of a ship to withstand the attack which it is likely to meet does not consist in the aggregate weight of armor which it carries, but in the disposition of that armor. The small iron-clad which Mr. Scott proposes to build would be somewhat similar in construction to the "Enterprise" and "Research," upon which Mr. Scott's plan is undoubtedly an improvement. He proposes to construct his vessel with a central fort with curved ends, both the sides and ends being armor-plated to a depth of about 6 ft. below the water-line when the vessel is at fighting draught. This fort is intended to have an iron-plated shot-proof deck, and within its walls are the bases of the guns, ventilating, covering, and funnel turrets. There is to be no side armor before and abaft the central fort. Extending from the ends of the fort and covering the hull fore and aft, at a depth of about 6 ft. below the water-line (fighting trim), there will be a shot-proof armored deck; above this armored deck, and rising with a sheer fore and aft, the hull of the ship is similar to that of an unarmored vessel of war. About 6 ft. above the armored deck (fore and aft the central fort) there is another deck of thin plate, the space between these two decks being divided into water-tight compartments, which would be in

communication with the ship's pumps, and there would be wing spaces between these compartments and the top sides of the ship, which would afford facilities for stopping shot holes or repairing damage sustained in action. Above these compartments (which Mr. Scott calls the deck tanks) and at a minimum height of 7 ft., is the upper or spar deck, and the space between this deck and the tank deck affords accommodation for officers and crew when the ship is out of action. It will be seen from what we have above stated that a ship built upon this principle would be comparatively light at the ends—a difficulty hitherto experienced in the construction of iron-clad ships. Another advantage which Mr. Scott's ship would possess over a "breastwork" monitor would be the larger area embraced within the central fort, thereby affording increased facilities for working the turrets and guns.

We now come to another important feature in this ship. For every day that a ship is in action she is years out of action, and therefore it becomes a question of great importance that the crew should have a ship which is fit for them to live in. It is, to say the least, not an unimportant matter that a ship should be properly lighted and ventilated, and rendered a fitting floating habitation for men. When fighting at close quarters Mr. Scott's ship's draught of water would be increased by admitting water into the winged spaces and deck tanks, and also between the double bottom of the ship, if built upon the double bottom principle. It will be understood that if the deck of a "breastwork" monitor is penetrated there is nothing to prevent the shot traversing the ship; but in Mr. Scott's ship the armored ends of the fort are carried down to about 6 ft. below the water line, where they join the armored deck fore and aft of the fort, whereby the passage of projectiles is prevented. From what we have briefly stated our readers will see the advantages which Mr. Scott believes he will gain by this system of construction.

Small iron-clad ships carrying one or two big guns are required to render the British fleet perfect. At present we have no such ships. We have seen how powerless the French fleet has proved in the Baltic. We have also seen how this great fleet of heavy ships has been teased and worried by one or two small vessels with a big gun or two on board. It is impossible to build a ship of small dimensions which shall be entirely plated with armor of sufficient thickness to resist the fire of modern artillery; all we can do is to protect in the best manner possible the vital parts of a ship, and we shall be glad to learn that Mr. Scott's plan has been favorably received by the Admiralty.

ON THE PROCESS OF INCLINING A SHIP IN ORDER TO FIND HER CENTRE OF GRAVITY.

From "The Engineer."

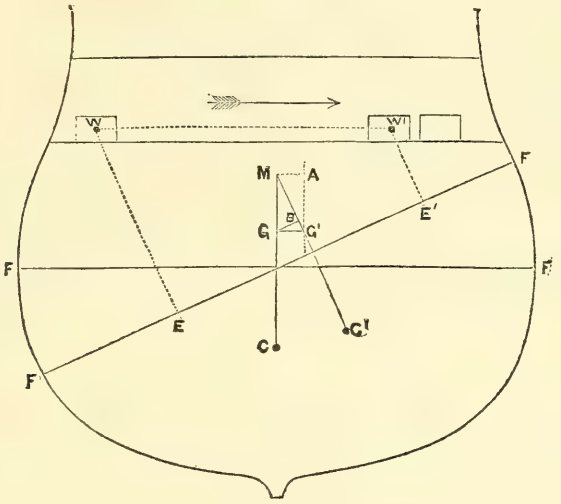
Questions connected with the stability of ships have recently attracted so much attention that we feel sure the following paper will be appreciated by readers of "The Engineer." We have in it explained as simply and plainly as possible the *rationale* of the entire process of inclining, as practised in her Majesty's dockyards and elsewhere. The method of finding experimentally the position of a ship's centre of gravity, by measuring the angle of heel produced by a given alteration of the distribution of weights on board, has been known for nearly a hundred years. It is described in various treatises on naval architecture. Its practical introduction into Britain, about 1830, is due to Mr. Isaac Watts, C. B.

Full details of the process, illustrated by several examples from actual experiments on ships of the British navy, are given in a paper by Mr. F. K. Barnes, in the "Transactions of the Institution of Naval Architects," for 1860.

The principles on which the method depends, are the two following: 1. When a body floats in a steady position, the centre of gravity and the centre of buoyancy are in one vertical line. 2. If the centre of gravity of any part of a body be shifted in a given direction through a given distance, the centre of gravity of

the whole body is shifted in a parallel direction through a distance smaller than the given distance in the same proportion in which the weight of the shifted part is smaller than the weight of the whole body. The centre of buoyancy of a ship coincides with the centre of gravity of the mass of water that she displaces; and its position is found by well-known processes of measurement and calculation, when her lines and the position of her plane of flotation are given.

The experimental operations to be performed when a ship is inclined, are the following: The ship is in the first place trimmed so as to float upright, all heavy bodies on board being secured so that they cannot shift of themselves when she heels. Then some part of her lading (such as guns or pig-iron) is shifted in a transverse or thwartship direction, so as to make her heel over; the weight of each shifted mass and the distance through which it is shifted, being carefully meas-



ured and noted. The angle to which the ship is steadily inclined or heeled over is observed by the help of suitable instruments; and for this purpose it is usual to fit up plumb lines and scales in the hatchways.

The processes of drawing and calculation are as follows: Let the figure represent a body plan of the ship, and let FF be her plane of flotation, and C her centre of buoyancy when in the upright position. Then it is known that her centre of gravity must be situated somewhere in the vertical line CM, which traverses the centre of buoyancy; for that is the line of action of the resultant upward pressure of the water, by which the ship's weight is supported. Let F_1 F represent the plane of flotation when the ship is heeled over to the angle observed during the experiment, and C^1 the corresponding position of the centre of buoyancy, found by measurement and calculation, according to the rules already mentioned. Then C^1 M, perpendicular to F^1 F^1, will represent the new position of the line of action of the resultant upward vertical pressure of the water; and the centre of gravity of the ship, when in her inclined position, must be situated somewhere in this line. Multiply each of the shifted weights by the distance through which it was shifted transversely during the experiment, and add together the products. For example, let W be the position of one of the weights when the ship was upright, and W^1 the position to which the same weight was shifted in order to incline her; then multiply the weight W by the distance $\overline{W\ W^1}$, and add together that product and all the corresponding products for the other shifted weights. Divide the sum of these products by the whole weight of the ship with everything on board; in other words, by her displacement. The quotient will be the distance through which the centre of gravity of the ship was shifted transversely during the experiment.

Let M A represent that distance, laid off transversely, that is, parallel to $\overline{W\ W^1}$,

from the vertical line C M. Through A, and parallel to M C, draw A G^1, cutting M C^1 in G^1. This point will represent the centre of gravity of the ship when in the inclined position. Then through G^1, and parallel to $\overline{A\ M}$ and $\overline{W\ W^1}$, draw $\overline{G\ G^1}$, cutting C M in G; this point will represent *the centre of gravity of the ship when in the upright position.*

To find by calculation the depth M G of the centre of gravity below the point of intersection M of the two lines of upward vertical pressure, C M and C M^1, multiply the calculated distance $\overline{G\ G^1} = \overline{M\ A}$ by the cotangent of the observed angle of inclination, C M C^1.

At small angles of inclination the point M sensibly coincides with the metacentre, whose height C M above the centre of buoyancy in the upright position may be calculated from measurements on the plans, so as to avoid the necessity of determining the centre of buoyancy C^1 in the inclined position. The same is the case, even at large angles of inclination, provided the ship is of such a figure that the intersection M does not sensibly change its position as she heels over. This property belongs to most of the ordinary forms of large ships, but not to those which either flare out or tumble home to an unusual extent, or which heel over so as to immerse the gunwale; and in them the position C^1 of the centre of buoyancy, when inclined, should be found by special measurements and calculations.

The statical moment of the forces by which the ship is inclined, and the equal and opposite moment of the forces with which she tends to right herself, may be calculated either by multiplying each of the shifted weights W by the projection $\overline{E\ E^1}$, on the plane of inclined flotation of the distance through which that weight was shifted, and taking the sum of the products; or by multiplying the displacement of the ship by the perpendicular distance, G B, of her centre of gravity when she is upright, from the line of action, C^1 M, of the resultant upward pressure of the water when she is inclined.

TECHNICAL EDUCATION—THE RENSSELAER POLYTECHNIC INSTITUTE.

(*Continued from page* 13.)

When a graduate leaves school and goes to work in any department of engineering into which the mechanical element largely enters, such as constructing and erecting machinery, mills, engines, buildings, bridges, and fixed plant, his very first step and every succeeding step call for ready and accurate knowledge on the following subjects:

1. On the use of mathematical processes and instruments.

2. On the theoretical strength and stability of materials and structures, or the application of mathematical formulæ to certain known shapes and properties of materials.

3. On the mechanical powers.

These are so thoroughly taught at the Rensselaer Institute, that little improvement is at present possible or desirable.

4. On the principles of prime movers.

5. On the fundamental principles of the mechanics of solids and fluids.

6. On the fundamental principles of Physics.

These subjects are certainly the basis of any reasonably thorough engineering education.

The important question now arises—are these the only, or even the most important elements of practical education that are *attainable in a school*, considering the nature and scope of the professional problems of the period? Is this all that can be practicably taught by books and lectures? To answer this question, let us examine in detail several of the more important problems that the graduate has to face the first day he begins practice. In whatever branch of engineering he commences, whether in mining, machinery, tools, fixed works, transportation by land or water, metal working, water supply, or agriculture—whatever part he may take in utilizing the forces and materials of nature, his right hand ally is the *steam engine.* In the present state of mechanical and constructive arts, steam power is the rule and all other prime movers are the exception. Animal power is too slow

and costly even to dig in a bank or to carry a hod, in large constructions; wind power is too fluctuating to propel coals from Newcastle to London, and water power is rarely availably situated. We hardly realize, until we stop to reflect, how universal are the offices of steam power. Not only is it the essential principle in transportation and manufacturing, and a part of the permanent works wherever force is artificially applied, but it is the essential motor and tool in mining, construction, erection, agriculture, and the preparation of materials. Wherever there is work to do, in the bottom of a shaft, under the bed of a river, in the air, under water, afloat, ashore, in the elaborate water-works of a city, in the farmer's barn-yard, driving a ship's screw, hoisting bricks and mortar, blowing a furnace, hauling a plough, sawing boards, digging for foundations, making watches, laying masonry—in short, in preparing, transporting, and putting together the materials in every branch of construction and manufacture—for all these purposes the engineer must be prepared, not merely to set up a steam engine just as if it were a brick or a fence post, but to select or to adapt a steam engine and boiler with reference to first cost, economy of fuel, available space and convenience of maintenance, and to the particular kind, amount, and duration of the work to be done.

Looking at the steam engine in this light, which is certainly the proper way to regard it in these days, it is difficult to believe that there is any professional subject, except the use of mathematics, upon which the engineer needs more accurate and varied information. And yet, the principle upon which steam engineering is studied in our schools is, that if a graduate can calculate the ultimate strength of parts and the general dimensions of one text-book type of engine—usually an extinct type—all other attainable knowledge on this subject is of the practical kind, that must be picked up in the shops, as experience or subseqent investigation reveal it.

The argument against teaching what is called practical engineering, in schools, is that we cannot expect to make machinists, contractors, and experts in specialties, during a four or five years' university course; that students have neither opportunity nor time to follow out consecutively, in machine shops, iron works, and engine rooms, the various operations by which a thorough knowledge of steam engineering, for instance, can be acquired; that experience is not merely a substitute for books, but that it is an indispensable element in working knowledge. All of which is true, and should be specially commended to the managers of technical schools where working in a small machine shop is a part of the curriculum.

But this objection does not meet the case under consideration. Continuing the illustration of the general subject, by means of the steam engine, we find the following branches of knowledge, in addition to mathematics, necessary to an intelligent, judicious, and economical employment of that agency, in the various cases likely to arise in the practice of any engineer.

1st. An intimate knowledge of the mechanical theory of heat, and familiarity with the formulæ and physical conditions necessary to draw practical conclusions from it.

2d. The law of the expansion of steam; with reference to condensation by expansion, compound cylinders, high piston speed, super-heating, clearances, and the lap, lead, motion, and other functions of valve gear. A student may as well know nothing about the law of expansion, as to know it independently of these conditions.

3d. The law of combustion, not merely as a laboratory experiment, but with reference to available room, time, furnace materials, and fuels.

4th. The law of the flow of fluids and gases, with reference to changes of temperature, distances, and initial pressures.

5th. The laws of the expansion of metals, not merely abstractly, but under the ordinary conditions of temperature and friction.

6th. The laws of friction, reference being had to the conditions of service,—that is to say, afloat or ashore; in a dusty rolling mill, or in a clean engine room; and the possibility of extra stress, as in locomotives.

7th. The relations of heating-surfaces of different kinds and in different positions relatively to the fire and to the gas currents; and of grate surfaces and openings with respect to different fuels; and

of water spaces, circulation, separation, and steam room, for various kinds of service.

8th. The principles of calculating power and of making allowances for frictions, condensations, and losses, by means of formulæ, indicator cards, and water and fuel used; and also, of determining the dimensions of boilers, condensers, cylinders, etc., from estimated power.

9th. The principles of calculating the power required for different purposes, such as for propelling mills, machines, and vessels of given shapes, and also the principles of constructing and determining the results of dynamometers.

10th. The character of materials used in construction—not merely their ultimate strength, but their adaptability to particular uses, with reference to temperature, moisture, friction, expansion, and working stress of all kinds.

The improvements which have, since text-books were written, entirely revolutionized the economical use of steam power; the new discoveries, inventions, and adaptations which characterize the modern steam engine, are chiefly founded on the knowledge of the laws here stated, and upon such knowledge further improvements are likely to proceed. This is especially true regarding heat, in the various phases in which it is dealt with by the steam engineer—expansion, condensation, combustion, etc.

Nor is this knowledge available only with reference to the steam engine. The laws of heat, combustion, friction, expansion, the flow of fluids, the estimation of power, and the nature of materials—not merely in the abstract, but as they are encountered in practice, are of universal application.

Yet these are the branches of knowledge which are least thoroughly taught in schools. Some of them are not even alluded to throughout the course, and must be acquired, if at all, when the necessity arises for their use, which is immediately upon graduation; and they must be acquired, to a great extent, by the same means and processes that would be employed in a school, for they are all, or nearly all, of such a character that no mere practice or experience can impart them at all, or even make place for them, without great waste of time. In short, the greater part of the existing knowledge on these subjects is to be found in the professional literature, and may therefore be imparted to students in lecture-rooms. It is not indeed found in the text-books at present standard, but it exists in a shape that can be reduced to the didactic form without great difficulty. The *means* of imparting this knowledge will be considered in another part of this report.

Your committee are of the opinion, in view of the universal application of steam power, of the great variety of conditions under which it must be used, of the immense amount of positive knowledge that is recorded on the subject, and of the adaptation to general purposes of the laws which govern steam, that the degree of Engineer should not be conferred upon the graduates of a high technical school, unless it is founded upon at least a respectable acquaintance with the subjects above enumerated.

Your committee do not underrate the importance of experience; of that practical judgment which books cannot give; of the many and invaluable teachings which nothing but repeated personal failure can impart; of those ideas which enter the brain through the fingers; of that imperceptible education of the senses; of that sympathy of the man and the machine which is akin to the sympathy between the members of the human body—of all that varied and invaluable knowledge which, without necessarily imparting skill, rounds and harmonizes the education of the engineer.

Nothing can be more injudicious—no feature of technical education in schools is more injudicious, than the idea, imparted or implied or uncorrected, that the instruction derived directly from workmen, from materials and from machines, in the workshop and in the field, is of a lower grade than that imparted in the academy. If the choice lay between these two methods of instruction—if the one or the other must be abandoned, the skilled laborer, graduated by the district school, and perfected in science by his weekly technical newspaper, would perhaps make a better record than the most elaborately finished bachelor of text-book engineering. The intelligent and ambitious mechanic almost inevitably stumbles into enough theoretical knowledge to

carry out with confidence, independence, and commercial success, some department of construction or manufacture. But the mere theorist—the student whose text-book culture has not been illuminated, and, so to speak, incarnated by constant reference to and dependence upon practice, rarely acquires in after-life the counterpart of a *working* education. Mere mathematicians and scientists often form a part of a thriving engineer's plant and machinery, and however valuable their functions may be to *him*, they do not often acquire reputation and fortune for themselves, in connection with great engineering works. The history of engineering affords many illustrations of this fact.

These considerations indicate that an engineering education cannot be *completed* by books; but their more important, and, we fear, less appreciated lesson is, that the culture imparted by books, should have intimate relations with the best, the latest and the current practice.

The knowledge which enables a man to practise mechanical engineering, classified according to the methods by which it may be acquired, is of three kinds.

1st. Theoretical, so called, or, more properly, *rational.* This, whether acquired in schools or in the intervals of practice, is attained by the same methods and from the same sources.

2d. Practical, so called, or more properly, *experimental,* which is the result of practice and experience alone.

The third kind partakes of the theoretical and the practical, and cannot be successfully acquired without constant reference to these co-ordinate means of instruction.

There is no difficulty in distinguishing between the first two departments. The difficulty is that the schoolmen do not classify technical instruction on this principle. According to their classification, the proper subjects for academic culture are those that are embodied in text-books. All the rest is thrown over into the post-graduate course, under the general head of practice.

Now the notorious fact is, that there are no recognized text-books of what may be called modern mechanical engineering—of the steam engine of the period, of steam agriculture, of the sewerage of towns, of naval architecture, of the present machinery of offence and defence, of steam on canals, of permanent way, of mining and excavating machinery, of iron buildings, of storing and utilizing the power of wind and tide, of the new system of railway practice known as the "light railway" and "steam carriage" system, of modern pumping, hoisting and blowing machinery, of the machinery for accumulating power and transmitting it through long distances, of roll trains, steam hammers, and the iron working machines of the day,—of modern engineering in general. There are no text-books on these subjects, but there is a very comprehensive literature, a definite practice, and a teachable science. These are the subjects which will involve three-quarters of the capital, the talent, and the professional learning of the coming years, and the first thing the graduate of a technical school has to do after being solemnly labelled "Engineer" on commencement day, is to learn the theory of his business—to again place himself under a course of literary instruction. In some instances known to your committee, the graduate has actually to unlearn the antiquated and superseded lore of the text-books. The principles of constructing, arranging and proportioning steam engines, for instance, as taught in certain technical schools, are positively noxious, and all those improvements that characterize and define the modern steam engine, such as expansion in double cylinders, surface condensation, super-heating, and rapid cut-off, are entirely ignored.

There are no text-books, in the English language, of pattern-making, founding, forging, finishing, and of iron and wood working machinery. Engineers need not, indeed, acquire skill in these departments, but a knowledge of their principles and capacities is absolutely indispensable, and can be acquired in a school, by the aid of drawings and models, much more comprehensively and harmoniously, in a given time, than by actual practice. This class of instruction will be again referred to.

Your committee are of the opinion that the importance of imparting the most modern and practical information is fully appreciated by the Faculty of the Rensselaer Institute, and that the want of a sufficient number of instructors and of time and place in the course of study, for the modern branches, is their chief embarrass-

ment. The general theory, however, obtains, in all our technical schools, that the information they are to impart, is chiefly that derivable from books written for the express purpose of academic instruction. The idea of selecting parts of the standard technical books and monographs—of courses of reading and examination in the technical serials, and of lectures and examinations founded upon the current literature and practice, is not entirely novel, but it is revolutionary, and will be farther considered.

Your committee do not forget that one of the chief offices of any system of study is intellectual drill—training the mind in the processes and habits of work. It appears merely to suggest, under this head, that if the purely mathematical part of the course is not rigid enough in this direction, the problems of mechanics, chemistry and physics, are sufficiently abstruse for all purposes of mental culture.

With regard to the third division of engineering education—that which is derivable from books and oral teaching, constantly illustrated by and referred to practice, there is a variety of opinion. The subjects that we have so far considered, are as purely theoretical as are the calculations of the strains in a bridge. There is no question about the proper method of teaching these subjects. They are, indeed, distinguished from ordinary theoretical studies, not however by being founded on practice, but by being founded on modern and current practice.

We now come to a department of education, into which the experimental element must largely enter. Is it practicable to teach it, or the rudiments of it in a school? Is it not even better that the practitioner should study theories in the intervals of practice, than that the student, already crowded with new theoretical studies, should take the necessary time to learn, or rather half learn, the practical part, in the places where construction and manufacture are going on? Is not the legitimate function of a professional school simply to train the student in the intellectual tools of the profession? This is the theory that usually obtains; but there is a widely different system already in use, at the Washburn school in Worcester, for instance, and about to be introduced at the Stevens school in Hoboken. These institutions embrace a working machine-shop among the apparatus of instruction.

It appears to your committee that a four or five years' course is already so crowded with theoretical studies, that the addition of a course in skilled labor would be impracticable, even if necessary. Only a small part of the practical training of the engineer can be obtained in a machine shop. Were an iron-works, a railroad and a steamship added to the plant, and another five years to the course, the graduate of such a school would doubtless be better trained than the ordinary graduate of five years' standing. Such an establishment would of course be impracticable, and it is possible that the students in a machine-shop institute, being constantly told that they were learning practice as well as theory, would become narrow and limited in their ideas, and would attach insufficient importance to the counterpart of their education yet to be derived from the business pursuit of the profsssion. In short, such schools seem to be rather industrial than scientific.

But there is an intermediate class of knowledge, which has been imparted, as yet, on a very limited scale, in American schools. The extent to which it may be, and should be, taught in schools, is best explained by an illustration. In every machine and engineering structure, a certain element of stability has to be provided for, in addition to all those resistances to the measurable strains that can be calculated by rule and formula. Excessive amounts of material must be put into various parts, such as bed-pieces, simply to provide inertia—to prevent trembling and chattering. There is no rule for such cases; in perfected machines, these proportions have been taught simply by repeated breakdowns, and in newly designed machines, they are usually a matter of judgment; experience alone can fit a man to provide for them. But should not the graduate know beforehand, that he must encounter this problem? It is not practicable, by means of a lecture or two, even to give him a general idea of its nature, illustrated by a comparison of the actual with the theoretical dimensions of parts subject to vibration, in standard machines? Half an hour's explanation, aided by a few drawings and calculations, will give a whole class such an idea of this

element of design, that they will at least know that they have got to know more, and when and where to look out for it. These preliminary hints, save not only time in acquiring farther information, but they may save money and lives, by warning young designers of danger ahead.

This is but a sample of the many practical problems which must indeed be worked out in the field, but of which the pass word can be given in the recitation room.

Pattern-making, founding, forging, plate working and the capabilities of machine tools, rolls and hammers, are not even referred to in many schools that profess to teach engineering, and the reason given by the schoolmen is, that the object of a school is not to make artisans to execute, but engineers to design. Now it is a notorious fact that the machinery first designed by graduates, contains pieces that can neither be cast, forged, rolled, fitted up, put together, taken apart or repaired with any reasonable economy, if at all. We do not expect inexperienced men to compete with established practitioners, and we do expect designers, however learned, to consult with expert artisans as to the details of economical execution. But is it too much to expect one more thing, viz.: that a graduated engineer shall have some idea of what tools will do and what they will not do; of what can and what cannot be executed; of the functions and capabilities, not only of the things made, but of the things that make them? If a graduate has no ideas on these subjects, he is still a student of theory; after he begins practice he cannot be trusted with any detail of design or execution; he must be constantly watched; he is a mere copyist or tool till he has mastered the rudiments of these subjects; and as his education is not the object of his employer, he is not taken about and lectured and drilled and corrected and examined and made to understand these things. He gets his rudimentary knowledge of them by the longest, the hardest, and the most roundabout course, and it is in acquiring these rudiments that the neophyte meets his most serious delays and embarrassments. They are easily enough acquired when they are specially pointed out, and their development and application follow upon practice, as a matter of course. But they are not specially pointed out. It is a common and serious mistake to suppose that mere employment in engineering work is of itself a systematic and comprehensive course of instruction. For the very want of this rudimentary knowledge, the novice is usually kept in a groove where he can be made useful; no instructor is appointed to tell him what things outside of that groove he ought to learn, or how and where to find the information. He has to establish his own curriculum and be his own schoolmaster. There is no professor watching over him, to show him what to study and to see that he learns it. A man may be a draftsman, or a mathematician, or an assistant in one or two departments for years, and yet have so limited a knowledge of the capacities of tools, materials and processes, as to be unable to design and execute independently—on his own account.

Now cannot our schools, instead of giving their graduates no hint on many of the subjects they will inevitably encounter before they can earn a living—cannot our schools say to their students: "We cannot give you experience, nor judgment, nor mechanical instinct, but what we can do is to smooth the way and shorten the course? We can at least prevent your groping in the dark after knowledge or going for years without it because you do not know what kind of knowledge you want and where to look for it."

Sending men out of a school, full of mathematics and text-book science, but ignorant of even the existence of the coordinate branches of knowledge yet to be acquired, appears very much like sending a ship to sea without a chart. The school furnishes its offspring with an engine, a rudder and a compass, and then says to him: "Now be off—you have many ports to make, and when you find them, you'll know where they are!"

Your committee are aware that these considerations are unorthodox, if not revolutionary, and that if they should appear plausible, they should not be adopted hastily or without more extended investigation. But when your committee see all over the country, mechanical engineers without remarkable talent, without any culture except that derived from the common school, the professional newspaper and practice, executing important works and making great names and fortunes,

and when they see in the drawing-rooms of these very engineers, men of equal natural capacity, who *have* been labelled experts, and who for the want, not of experience, but of a ready guide to the fruits of experience, are for another four years or more, simply copying and calculating *machines*, they cannot avoid the conclusion that there is a missing link in the present system of technical instruction. It is a general fact, that not until after as many years of practice as are required by uneducated men, do the graduates of our technical schools achieve the positions due to their advantages.

Should it appear desirable to modify the curriculum of the Rensselaer Institute in accordance with these suggestions, the question arises, by what means is it to be done?

In the absence of text-books, it must evidently be done by lectures founded on the modern and current practice, and illustrated by models and drawings, by courses of reading in technical publications, and, as far as time will permit, by a sufficient examination of works and processes in progress, to explain and utilize the theoretical instruction—and finally, by as rigid a course of examination in the knowledge thus imparted, as in any other department.

The first difficulty would appear in providing time for such a variety of instruction. But this difficulty diminishes upon examination. Those studies last considered, which may be called *guides to practical studies*, although large in scope, do not purport to cover all the cases that may arise, but to group the more important ones into classes, and to illustrate each class by going into detail with a few representative cases. For instance, in a single lecture, the whole subject before alluded to, of vibration as affecting the stability, wearing out, and capacity of machines and structures, could be sufficiently elucidated for this purpose. A number of cases would be mentioned under the head of *remedy by elasticity*, such as placing wooden cushions between the parts of a steam hammer frame, and under an anvil block, and between the tyre and rim of a locomotive wheel, and in an iron railway sleeper, and generally, where there were sudden shocks, and where at the same time no objection existed, such as getting accurate machinery out of line. This class of cases would be illustrated by a short specification or two, of proportions and arrangement with reference to load and stress. Another class, under the head of *remedy by stiffness and inertia in detail*, would be illustrated, after a general reference to the principal examples, by the steam engine, in which not only the bed plate but the connecting rods, the shaft, and other parts stand in such relation to the strains, that no mere mass in the foundation piece will answer the purpose; in which, especially when portable or locomotive, great weight is inadmissible and stiffness must be obtained by bracing; and in which the rigidity required to keep the machine in line, and the absence of violent shocks, render elastic media improper and unnecessary. A third class would be illustrated by the machine tool—the lathe and planer, in which the stress is of such a character that mere mass and inertia in the framing are indispensable, and elastic media are harmful.

Lectures on this plan should be carefully prepared after consultation with the best practitioners, and should be followed up by a rigid examination of the student, not only on the cases considered, but on the principles involved. In such cognate subjects as bearing surfaces, the convenience of taking machines apart for repairs, lubrication, boiler-setting, lining or adjusting machinery, temporary hoisting gear, blocking and false work, pipe-fitting, pattern making, the principles, capacities, and economies of foundries, machine tools, special tools, forging, plate and sheet-iron working, the behavior of metals, woods, and materials under stress of heat and moisture, and their qualities, grades, brands, and sources of supply; and some rudimentary ideas as to the value of materials and labor, and the commercial forms for obtaining them—these and some other practical subjects may be not only mapped out, bnt they may be so far explained and impressed by one lecture apiece, that the graduate will know just where and how to learn more. Probably twenty lectures, or say one month, devoted to this class of subjects, would save the graduate many months of delay and disappointment in his early practice.

Another class of lectures of a theoretical character, would be more exhaustive, and hence would require more time. Their

subjects have been already indicated in some detail. Such lectures should, of course, be made up from the best technical publications, corrected by current practice. Each lecture should probably be brief enough to be fully copied from dictation by each student; the reading of certain illustrative sections or articles in books, papers before learned bodies, and engineering magazines, should be prescribed; and the examination should cover both the lecture and the reading. The whole mass of professional literature thus becomes the text-book; but only a specified portion of it need be read. The lecture would be both a guide to the readings and a recapitulation of their teachings.

It is probable that lectures on the subjects specially requiring such illustration, should be clinical—that is to say, delivered in the shops and on the ground where work is going on. This plan presents some difficulties in respect of time and opportunities. A great deal of illustration can, however, be accomplished in a very short time, if the lectures are properly adapted and the accompanying drawings are numerous and intelligible. A class may wander about a machine shop or a rolling mill all day, and learn absolutely nothing; while if their minds are prepared, if their interest is awakened, and their attention is concentrated on the particular detail or function to be elucidated, a single look and five minutes talk may produce a sufficient and lasting impression.

Too much importance, however, may be attached to clinical lectures, and to the spending of undergraduate time in the shops. The *working drawing* is the professional language of the engineer, written in short-hand. He builds from drawings works that he has never seen; more than this, he builds from drawings works that have never previously existed. From a set of sections, elevations, and details, the best attainable knowledge of most machines and engineering works may be obtained—better, indeed, than from the works themselves. The rapid reading of drawings is not the highest attainment, but it is the most useful accomplishment of the engineer, and for the purposes of education as well as practice, should be the first and the most thoroughly acquired. Such lectures, then, may not only be well elucidated by drawings, but they may, in addition to the particular illustrations conveyed, perfect the student in the most useful art of his profession.

Tracings from the working drawings of all the best works and machines are not difficult to obtain. Almost any establishment would furnish them at cost, to a school; many establishments would present them; others would lend the originals, and the students might copy some of them for the school, while acquiring the manual part of the art.

Models are of course important; there is hardly a limit to their usefulness, and in some departments they are indispensable. But where types of the works themselves are within reach, and drawings are full, a large museum of models is not absolutely essential.

Your committee fully believe that such lectures, readings, and examinations, illustrated by standard and numerous drawings, and as far as may be by models and originals, are the only practicable method of imparting at least a third part of the information that the graduated mechanical engineer ought to acquire in a school. The place and extent of this part of the course, your committee could not undertake to specify at this time, or without the advice of the Faculty.

The remaining and apparently the most difficult question is: How are such lectures to be provided for? Who is to give them and how are they to be paid for?

A single professor of mechanical engineering would not be able to prepare and to teach the whole or even the half of the course. He would not have time to make all the necessary selections from the current and standard literature, either for his lectures or for the reading of the students; and probably no individual, certainly no one who could be secured, has had both theoretical learning and practical experience, on a sufficiently comprehensive scale to fit him for all these varied duties. Besides, as has elsewhere been shown, half the time at least, of such a professor, would be devoted to aiding the present corps in the enlarged teaching of the old and some of the new branches to the students at large. A professor of mechanical engineering should probably take the general charge of the course, in

as far as it was not coincident with the course in civil engineering and with the studies common to all courses, and he would teach the more general branches of his specialty, such as heat, the laws of the expansion of steam, etc., both by text-books and lectures.

The other theoretical branches hereinbefore enumerated as being essential to the course in mechanical engineering, and also those referred to as guides to the practical studies, would have to be taught by *non-resident professors*—by men actually engaged in the constructions and operations to be investigated. Not every practitioner could prepare the required lectures, however well he might execute the actual work, but the number of experts who could is very large. Such men, by giving one lecture each, on some branch to which their reading and practice had been specially devoted, would hardly miss the time taken from their own pursuits, and would add immensely to the value of the course and to the renown of the institution. Such a lecturer need not necessarily be a teacher by nature or by profession, although it would be better that he should assist in conducting the examinations upon the lectures. But if he would simply read a plain, comprehensive statement of the facts and principles in the case, stripped of all that unpractical, superfluous matter *which experts only can avoid*, the professor having charge of the course could conduct the examination and assist in the merely didactic part.

Many such men do devote, every year, without pay, an equal amount of time to the preparation of papers before professional societies, which are but schools of a higher grade, and these papers are on the whole the best didactic literature of the post-graduate course.

Your committee have little doubt that if a proper effort were made, a dozen eminent or at least capable and growing engineers could be found who would be willing to devote enough time during the next six or twelve months for the preparation of say three lectures each, and who would then be willing to spend one week per year in Troy, at appointed times, to deliver them and to conduct the examinations—and to do this either without pay, or for merely nominal pay and their expenses. * * * *

The missing link between theory and practice, however, is not characteristic of the course in mechanical engineering alone, as administered in our technical schools. We are prepared to reiterate the views thus fully expressed above, with suitable modifications, in regard to the course in civil engineering. What practical or technical studies, and guides to practice, could be advantageously introduced into this course? We shall merely mention, the best *modern practice* in bridge construction, building of all walled structures, public and private, permanent way, canals, foundations, reservoirs, water works and water supply, sewerage, drainage, retaining walls, grading, dock construction, subaqueous engineering, tunnelling, excavation, transportation, lifting and transference of heavy weights, the character of materials, their sources, qualities, imperfections, special adaptations, etc. But there is one class of subjects, of which, above all others, it is highly essential that the civil engineer should have a comprehensive knowledge, and without which he is fairly disqualified to practise his profession, and that is machinery. Surely it is not too much to say that the civil engineer is a mere user of machines, and is bound to know the value, structure, economy, and capacity of his tools as truly as the hand mechanic of the workshops. We by no means urge that his knowledge should be as highly specialized, or as detailed, as that of the mechanical engineer; but that up to a certain point it should be as thorough and practical and available.

Leaving here the civil engineers, and turning to the mining engineers, we may ask, what is one of the latter good for who has no knowledge of the multifarious forms of pumping machinery, the steam engine, hoisting apparatus, boring apparatus, and the numberless mechanical appliances of his trade? These classes of machinery are not mere heterogeneous masses of wheels, cranks, gears, shafts, and iron frames, but they are embodiments and expressions of fixed principles, capable of being classified with reference to definite ideas, laws, and plans, and hence capable of being taught; and where can their principles and the generalities of their practice be taught so economically, comprehensively, and speedily, as at a technical school?

Need anything more be said to demonstrate the immense importance of a course in mechanical engineering to the other courses already in existence? It is possible that there are those who believe that a civil engineer may practise his profession properly without this knowledge, but the members of your committee, as practical men, know nothing about that kind of engineering. The conversations which the committee have had with graduates and practising engineers, in numerous branches, and also the letters of many of their correspondents, are full and ample authority for the assertion that the establishment of a mechanical school upon a basis similar to that proposed, would almost entirely remove the cause of complaint before adverted to. That it would attract to the Institute many students, we cannot doubt, knowing as we do the sentiments entertained by eminent machinists and manufacturers respecting the value of educated assistants and superintendents. To many of the students themselves such a course presents peculiar attractions, and even of those now graduated as civil engineers, many would have preferred the mechanical course had it been at their option.

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The present organization of the Institute includes a programme of studies in natural science. It may be well to note the fact that the Rensselaer Polytechnic Institute was originally founded as a school of science, and has drifted away from its original scheme into a school of the useful arts. This has been compulsory, and not a matter of inclination. Although there exists in the minds of many the desire to re-establish this noble school, your committee are compelled to report against any outlay of money beyond that which is already appropriated annually for the purpose, unless it be some inconsiderable sum necessary to accomplish an efficient prosecution of studies already in vogue. Your committee mean that they cannot recommend any establishment of this course upon a wider basis than the present one, though they are prepared to submit some suggestions respecting its conduct as at present organized. They are aware that by this recommendation they are opposing the wishes of many friends of the Institute. They are also aware of the high value of such studies in effecting scientific culture, and acknowledge the frequent importance of their practical applications. But the position taken with respect to them is entailed by the hard necessity of straitened means and utterly inadequate resources. To establish a distinct department and school of natural science upon a respectable basis would render necessary the building and stocking of museums, the collation of a vast and peculiarly expensive library, and the maintenance of a large additional corps of very expensive instructors, requiring an endowment of hundreds of thousands of dollars. Even then we should have the well-established reputation of Yale and Harvard to contend with before we could expect to draw patronage. Your committee therefore dismiss the idea of an expanded school of natural science without further comment.

But a certain proportion of study in natural science your committee consider indispensable to the engineer. First, however, let us define our view of the meaning of the term *natural science*. In the recent classification of the sciences, it is not held to include either chemistry, astronomy, or physics, which belong to the great class of *physical science*. It does include botany, zoölogy, geology, and mineralogy, or those branches which relate to the structure, classifications, and natural functions of organic and crystalline formations, as found in nature. Of these branches it is difficult to say how much is really essential. Of botany and zoölogy, probably very little is absolutely requisite. It will, perhaps, be sufficient, and certainly will be all that is now practicable, if instruction be confined to the larger clas ifications of animals, plants, and minerals, and the principles upon which those classifications are founded. This is rather indefinite, it is true, and may mean much or little, according to the construction various people are inclined to put upon it; but the limits will have to be fixed by the amount of time available for their instruction. The student who would avail most by these studies will, in many cases, be induced by the attractiveness of the sciences themselves, to seek further knowledge of them outside of the curriculum, and if his zeal be sufficient, it will not be difficult for him

to gratify his tastes. It has frequently been noted by instructors, that the natural sciences, by their inherent beauty and attractiveness, call out the enthusiasm of the student to such an extent that he is not content to rest upon the regular instruction, but pursues them independently, as matters of fancy and taste, and in not a few instances, to an extent detrimental to due proficiency in the other prescribed studies.

The subdivisions mineralogy and geology are deemed by the committee of greater importance, though even here they do not deem it essential to educate students to any high state of proficiency. Determinative mineralogy is certainly highly useful to the civil engineer, and indispensable to the mining engineer, who should be able to determine readily the minerals he encounters in practice. Geology, though nominally a single science, is really a group of natural sciences. It includes, in its higher developments, an extended knowledge of the branches, zoölogy, botany, and mineralogy, which are prerequisite to a knowledge of fossils, upon which, in turn, depends the ability to determine the position and relations of strata. It is highly essential to the mining engineer, being a necessary part of the knowledge which is to render him fit for his duties. It is also useful to civil and mechanical engineers, affording them a means of forming opinions upon numberless questions arising in practice. But there is a higher sense in which this science may be made useful to the man who is educated to practical pursuits. It includes, in the most condensed form, the highest degree of that noble culture derivable from the natural sciences, and exhibits them in their philosophical relations as no other form of scientific study can. At once eminently useful in a practical way, and adapted to the highest scientific culture, it seems well suited to supply certain marked deficiencies in the courses of study, and to alleviate their somewhat dry, harsh, and utilitarian character. Still, how far it should be pursued is questionable. Its utilitarian aspect should be kept chiefly in view, and hence we are inclined to think that a thorough course in Dana's Manual, with such extensions by lecture, or otherwise, as shall develop more fully and availably a knowledge of practical and economical geology, will cover all proper and necessary requirements—thus leaving to post-graduate study any farther proficiency which may be necessary for special applications.

The study of the physical sciences is a matter of grave importance. The physical sciences may be divided as follows:—

1*st*. Chemistry.
2*d*. Astronomy.
3*d*. Elementary physics.
4*th*. Higher physics.

Respecting the first subdivision, chemistry, the committee need to say but little. It is one of those comprehensive sciences which lie at the foundation of all the useful arts. Engineers and mechanics are daily called upon to use practically its principles and details. We believe that the efficiency of every section in the Institute depends upon a thorough knowledge of chemistry, almost as intimately as upon thorough discipline in mathematics. But how far each section should respectively pursue the study and experimental practice of chemistry, admits of some discussion. It is clear that the mining engineer should pursue it farther than either the civil or the mechanical engineer, since his profession is, in great part, a branch of applied chemistry. But the other sections should be able to make qualitative analysis, and be thoroughly versed in the general principles of inorganic chemistry. The programme of the Institute contemplates this degree of proficiency, though it has not been adequately carried out. The time allowed for laboratory practice has been insufficient, both to the mining and civil engineers, to accomplish the purposes of the programme, and it is recommended earnestly that, hereafter, sufficient time be allowed to the chemical department, to enable the students to reach the desired degree of proficiency.

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The subdivision of astronomy is one upon which the committee have but one recommendation to make, viz.: that the mining engineers be not required to receive instruction in spherical astronomy, and that their time and attention in this branch be confined to descriptive and practical astronomy. The same recommendation would hold for mechanical engineers. For the civil engineers it may be continued, the present programme being very satisfactory in this respect.

The next subdivision, elementary physics, is one upon which the committee have some suggestions to make. Inasmuch as this is preparatory for, and continuous with, higher physics, it will be proper to discuss them together. The term "elementary physics" is generally understood to include the greater part of what was formerly taught under the name "natural philosophy," from which it differs by no longer including the discussion of the five mechanical powers, the laws of falling bodies, gravitation, hydrostatics, and several other subjects—all of which are now treated under the distinct head, mechanics. While it has excluded these topics, it has taken to itself others, which did not belong to the old system of natural philosophy, viz. : the principles of chemical affinity, of atomic proportions, of the conservation of forces, and, in short, all those definite principles which serve as the basis on which chemistry is built. As compared with mechanics, it may be approximately defined as treating of the effects of forces upon *atoms and molecules*, and the relations of atoms to each other ; mechanics treats of the effects of forces upon *masses* of matter, and the relations of masses to each other. It will therefore be seen to be a fundamental science, upon which a whole class of higher sciences rest —precisely as algebra and geometry are fundamental with respect to the higher mathematics, and arithmetic fundamental with respect to algebra and geometry. Chemistry is the development of physics in a particular direction. The laws of heat, or thermodynamics, is a development in another direction ; optics, or the laws of light, in a third; acoustics, or the laws of sound, in a fourth; electricity, or the laws of polarity, in a fifth, etc. Elementary physics is fundamental, and underlies them all; it is, so to speak, the arithmetic of these sciences.

It will hardly be questioned that an engineer must know, in a general way, the whole compass of elementary physics. But how far should he pursue its special and analytical developments into the higher branches—chemistry, optics, acoustics, electricity, and thermodynamics? It is suggested here that you adopt, as a rule for determination, the measure of utility, and by this rule we think a conclusion will not be difficult. Thus, chemistry has already been adverted to and recommendation made. Optics is a branch on which we think the engineer needs no special knowledge beyond that required to comprehend the general principles involved in the construction of optical instruments, and to be equal to a diagnosis of their infirmities. No refined analysis of the undulatory theory of light is deemed essential. So also in acoustics; it is believed that the engineer will be abundantly able to comprehend the meaning of the fire-bell, door-bell, or dinner-bell without stopping to apply the calculus. Your committee think that these studies, as special extensions of physical science, could be dispensed with. They are taught in a general way, and probably to a degree quite adequate to the wants of students, in the text-books of elementary physics.

The study of the subject of heat, far beyond any degree now contemplated, or taught, in the Institute, seems to your committee worthy of urgent recommendation. It is at once an eminently difficult, profound, and practical subject, and (which is a little peculiar), not only does its utility increase with a refined and thorough knowledge of it, but its true nature and real utility do not become thoroughly intelligible until an advanced stage of knowledge is reached. The fact that heat is now the great motive agent, and that its economy is one of the great aims—perhaps the greatest aim—of modern engineering, are abundant reasons why the engineer should understand it. In consequence of recent discoveries, and the results of investigations in progress, its economy has become a matter of calculation, as perfect and demonstrable as the strains upon the parts of a bridge, or the resistance to moving bodies on land or water; and it is a matter of surprise to the committee that these facts have not heretofore been acted upon in the construction of the programme of the Institute. It is recommended that, in the place of optics and acoustics, the mechanical theory of heat be taught analytically to every section, mining engineers included. It must be mentioned that no text-book on the subject, in the English language, is known to the committee, excepting one or two, which do not seem to be satisfactory. There are, however, several in the French and German, thoroughly admirable in all respects. It has occurred to the committee, that as the

students receive a very satisfactory course of instruction in the French language, it might be advisable for students to use a French text-book on this subject. The committee do not make a definite recommendation to that effect, but merely throw out the suggestion for the consideration of the Trustees.

The subject of electricity is also thought worthy of special development, though its claims are not so imperative as the preceding. It is a branch of physics which is yearly becoming of greater and greater importance. The principles of this subject are usually dwelt upon with considerable minuteness in all text-books of general physics, and in view of the general stringency of the whole curriculum, the committee believe that it will be sufficient, at present, if the text-books of elementary physics be thoroughly and rigorously taught. But it seems that the instruction should be supplemented by lectures and experimental illustrations, since a knowledge of electrical machinery is quite as essential as that of principles, and it is difficult to see how this can be obtained elsewhere than in the lecture-room where the apparatus is at work.

Having thus gone briefly over the department of physical sciences, it will be noticed that, in several instances, increased proficiency has been recommended. On the whole, it will also appear that the committee have attached to these branches much higher importance than those have done upon whom has heretofore fallen the delicate and difficult task of arranging and balancing the various courses. It is readily conceded by the committee that they lack the advantages of judging the relative merits of these questions, possessed by experienced and learned instructors. On the other hand, they have had the compensating advantages of experience in the practical exigencies of the professions for which these studies are preparatory, and, after all, is it not by its adaptation to ends that any instrumentality must ultimately be judged? * * * * *

With regard to the general literary course, it appears to the committee that some advantage would be gained if such studies were distributed over the whole four years, instead of being confined, as at present, to the first two years. This might be readily effected, too, if, as has been proposed, the mathematical and scientific studies be pushed backward into the earlier years. The advantages of such an arrangement become apparent, when it is remembered that *time* is an essential element in literary training. That is to say, more culture will result from a given amount of study and exercise distributed over four years, than from an equal amount extending through two years. By the latter method the student is taught to write before he has developed his capacity to think, or has anything to think about. The true method should be to give him knowledge of *things*, and after that, he will be able to reflect upon them, apprehend their relations, and express them—which is the essence of rhetoric. At all other institutions, English composition and rhetoric begin, after more or less preliminary training, in a small way, and progress with increasing importance, until they become the culminating point of the whole system of academic instruction. This is doubtless the true plan; for the student's capacity to express is thus developed in direct ratio to his capacity to think, and to the amount of material he possesses to exercise his thoughts upon.

The present distribution at the Institute was made in order to accommodate those students who had enjoyed the advantages of a collegiate education, and enable them to dispense with the first two years of the course. It was assumed that such students had already received a thorough literary training, and that it was desirable to have this part out of the way when they were ready to enter. This reasoning is more plausible than accurate. In the first place, the number of collegians who enter the Institute are few in number, not exceeding two or three in each class, and it is undoubtedly better to submit these gentlemen to a reduplication of some studies, than to deprive the others of what is absolutely requisite. In the second place, it is by no means certain that a collegian may not derive very considerable advantages from a properly constructed course of scientific literature. The college graduate represents merely one phase of intellectual culture, and that phase is not merely distinct, but, in some respects, antithetical to that developed here. He represents the classical, the speculative, the abstract; ours the modern, the material, the concrete. He deals with

words about thoughts, and thoughts about other thoughts ; ours deals with words about things, and thoughts about things. He is the contemplative man of letters and philosophy ; ours is the scientific man treating of facts and realities. We raise no question here about the merits of the two systems, but are content to point out the differences. Whatever may be the culture and proficiency of the collegian who comes here, he has yet to learn how to think and write *scientifically*. There is a wide interval between the scientific and the merely literary way of treating a subject, and however much they may have in common—as, for instance, a common grammar, common figures of speech and rhetoric, and a common logical basis—the forms, fashions, and habitudes of the two methods are widely asunder. What should be the general character and scope of the literary training at the Institute, it is difficult to say with confidence ; but it should have for its object the development of a capacity to write upon scientific subjects in a suitable manner.

Respecting the means by which this end is to be obtained, it is suggested that the desired result will depend chiefly upon the personal efforts and determination of the student himself, more than upon books or exercises. No intellectual effort is more exacting of labor, and in none is progress more slow, than in the formation of style and method. The best that can be done is to keep the importance of the subject constantly before the mind of the student, stimulate his ambition, hold up the models before him, correct his errors, and exact general results, rather than good recitations from text-books. Much will also depend upon the instructor. He must have didactic powers far beyond what is necessary to clear up difficulties of text-books. He must be able to put life and enthusiasm into his functions, to sustain the interest and courage of his pupils, to draw out their thoughts, and to keep them constantly thinking. He must also possess general scientific culture, and tolerable familiarity with scientific literature and philosophy.

It seems to the committee that the following plan would contribute greatly to this branch of training ; and having no doubt of its efficiency, they would recommend it, viz.: that the student be required, during the last two years of the course, to prepare frequent essays and discussions upon professional subjects. During the third year, it would perhaps not be well to exact such efforts oftener than once a month ; but during the last year, their frequency should be increased to as often as once in three, or possibly even two weeks. Twenty to thirty exercises of this kind would amount to a fair preliminary training, and ought to give very marked results. Such performances should, by all means, be criticised chiefly with reference to style and method of treatment, and the standard should be tolerably rigid. The range of subjects selected should, as a rule, be confined to matters of detail, and not to largely expanded or broad themes—otherwise the writers will be apt to degenerate into loose, vague, inaccurate methods, and into that disgusting and foolish habit of generalizing, without anything to generalize upon.

Take an instance. Suppose a young man were requested to write a short essay upon crank-pins. Let him take a leisure hour, some afternoon, and visit the excellent establishment of Starbuck Bros. Let him inform the courteous proprietor what he wants, and in a few minutes, he will have learned that a little piece of steel, which might at first have seemed to him as destitute of high mechanical functions as a nail in a board fence, has relations which are intricate, scientific, and pleasing. Let him return to his room, and attempt to systematize his new acquisitions. Do not let him commence with Tubal Cain, nor with the pre-historic Swiss, nor with the tea-kettle, but at a rational beginning. With some little guidance, and some experience, he will be able to produce a concise, clear, logical, forcible little essay, containing more valuable and available material in half a dozen pages, or even less, than has been contained in all the theses to which it has been our questionable privilege to listen from the graduating students of scientific schools. He will have gained at least four things :

1st. Valuable practical information, not merely about one practical subject, and a part of a machine, but glimpses of practical relations to other and dependent parts.

2d. Some idea of what professional practice is, what unexpected difficulties it brings to light, and what kind of tempera-

ment, and what kind of means are requisite to overcome them.

3d. Some experience of a logical way of thinking about professional matters, and of professional insight.

4th. Some experience in putting ideas upon paper, so that when he has multiplied these experiences a few times, and entered practice, and when his employer sends him, as he is sure to do, to make a report upon some new process, or machine, or the details of some structure erecting, or long since erected, in other cities, he shall be able to send back a report, which will save his employer the necessity of going himself, after all.

Your committee have thus endeavored to convey to you the results of their careful investigation into the status of the Institute, and their opinions respecting its courses of study. Their work has been considerable, their reflection long and earnest, and though further insight might still modify their conclusions somewhat yet, in the main, they are satisfied with the general tendency of their recommendations. Throughout their inquiries they have endeavored to keep entirely aloof from all personal considerations—if such there were, which could influence either their judgment or their feelings—and to conciliate all true friends to the Institute. So far as their knowledge extends, they have succeeded in both these objects. That some of the propositions contained in this report may be considered strange and revolutionary; that they may excite distrust among the conservative, and awaken little confidence among those who will not take the pains to ponder them earnestly, we more than suspect. But we beg leave to state that we believe them to be sustained by the opinions of the most talented, promising, and accomplished graduates, and of the foremost mechanics and constructors of the country. Yet these opinions are not so revolutionary as they seem. It must be remembered that a great part of what the Institute must teach, is the reverse of fixed and unchangeable. It does not consist in dead languages, nor in immutable history, nor in changeless codes of law; but in the modern sciences which change their aspects as swiftly as the clouds of the sky, or the spots on the sun. It is the mission of others to treat of that which is fixed; ours, of that which is progressive; and our methods must change with our themes, and our practice with our facts. Nor are we by any means the first to recognize these things. It is the most comprehensive and noble function of European schools to provide for these changes—this fact of mutability and this ceaseless march of progress. The Conservatory of Arts and Trades at Paris, the great University of Zurich, the Schools of Freyburg, Stuttgart, Carlsruhe and Berlin, keep their greatest men in the background, where they devote their energies to this very end—keeping methods of teaching parallel with the requirements of practice, and only nominally, or perhaps never, to lecturing. How then can a school, in this mercurial country, teach the arts of twenty years ago, and hope to make a living by it? * * * * *

The committee have felt it to be their duty to speak strongly and earnestly on many subjects, which in the present methods and balance of the Institute, as well as of American technical schools in general, have met their disapprobation. But in so doing they wish to be acquitted of any intention to find fault with the present faculty. On the contrary, they warmly congratulate the Trustees and friends of the Institute upon the possession of a corps of servants so zealous, industrious, and eminently qualified to teach the studies which it has hitherto been found necessary to establish. If we have charged inefficiency upon any branch, we must once and for all be understood to attribute the cause of it to the utter impossibility of effecting greater results under present circumstances. But those impeding circumstances are what we attack, and what we hope to remedy; and as the Faculty have merited your sincere thanks and gratitude in the past, we feel assured that they will equally merit them under any possible changes of conditions in the future.

RECAPITULATION.

Recommendations of the Committee.

1. That the standard of admission be raised.

2. A conference with the Board of Education as to the use of the Troy High School as a preparatory department.

3. Less of mathematics and more of technics in the mining engineering course.

4. A school of mechanical engineering.
   a.—Addition to an improved theoretical course, of the course referred to as "guides to the practical studies."
   b.—The appointment of a new professor.
   c.—Non-resident professors.
   d.—Working drawings and models.
5. That no considerable extension of the course in natural science be made.
6. A thorough course in Dana's Manual, with some practical extensions.
7. That sufficient time be allowed all the sections to carry out the study of chemistry in accordance with the programme.
8. * * *
9. * * *
10. That the mining and mechanical engineering courses discontinue spherical astronomy.
11. That special extensions of optics and acoustics be discontinued.
12. A rigid course in thermodynamics.
13. French text-books in some departments.
14. Lectures on electricity.
15. A professor of physics.
16. * * *
17. Literary exercises through the whole course.
18. Frequent literary exercises upon scientific subjects.

DEEP SEA EXPLORATION—HOW SOUNDINGS ARE OBTAINED.

From "The Student."

The first point to be determined in the exploration of what are often called the "fathomless abysses" of the ocean, is their actual depth. This, it might be supposed, would be very easily ascertained by letting down (as in ordinary sounding) a heavy weight attached to a line strong enough to draw it up again, until the weight touches the bottom; and then to measure the amount of line it has carried out. But this method is liable to very great error. Although a mass of lead or iron thrown freely into the water would continue to descend at an increasing rate (at least until the friction of its passage should neutralize the accelerating force of gravity), the case is quite altered when this mass is attached to the end of a rope, of which the immersed length increases as the weight descends. For the friction of the rope comes to be so great when a mile or more has been run out, as seriously to reduce the rate of descent of the weight, and at last almost to stop it; and as the rope will still continue to descend by its own gravity (which, when it is immersed, considerably exceeds that of water), any quantity of it may be drawn down, without the bottom being reached by the weight at its extremity. Further, if there should be any motion, however slow, in the water through which it passes, this current acting continuously against the extended surface presented by the rope, will carry it out into an almost horizontal loop, the length of which will depend upon the rate of the flow and the time during which the rope is exposed to it. Under such circumstances it is impossible that the impact of the weight upon the bottom, even if it should really reach it, can become perceptible above; and thus the quantity of rope which may have run out affords no indication of the actual depth of the sea-bed beneath the surface. Hence all those older soundings which were supposed to justify the statement that the bottom of the ocean is not less in some places than 6 or 8 miles from the surface, or may be even absolutely fathomless, are utterly unreliable; and no value can be attached to any of these that exceed a few hundred fathoms.

Various methods have been devised for obtaining more correct measurements; but it is not worth while to describe any, save such as have stood the test of experience; and there is now a general agreement as to the principle on which an efficient sounding apparatus should be constructed, although there are several different arrangements for giving to it practical effect. The principle is, that regard should be had in the first instance, not to recovering the plummet, or "sinker," which is a matter of quite subordinate consideration, but to securing the vertical direction of the line to which it is attached, so that the measurement of the amount run out may give as nearly as

possible the actual depth of the water through which the sinker has fallen.

The earliest mode of sounding on this principle was a very simple one. A cannon ball is attached to a reel of twine, of known length, made to turn very easily; the shot being let go, and allowed to descend as fast at it reels off, reaches the bottom with the least possible impediment; and a breaking strain then being put on the line, the depth is estimated by substracting from its entire length the portion still remaining on the reel. This method, however, has not been found to answer in practice. For if the line be not strong enough to allow of being put strongly on the stretch, it cannot communicate the shock of the impact of the cannon ball upon the sea bottom; and its want of tension renders it liable to be acted on both by gravity and by ocean currents, to such a degree that it continues to run out indefinitely, long after the sinker may be supposed to have reached the bottom. It is an additional objection to this method, that even if it could be worked in such a manner as to give true results, these data would be far from satisfactory; since we desire to know not merely the depth of the ocean bed at various points, but the nature of the bottom; in addition to which it has now become a matter of essential importance to ascertain the temperature of the bottom water; while it is also desirable to obtain a sample of that water, for determining the composition of the gases as well as of the solid matters which it holds in solution.

For the attainment of these objects, it is now found expedient to adapt the following plan: The sinker is connected, not with the line itself, but with an apparatus which is so constructed as to detach it when it touches the bottom; and the line is made sufficiently strong, not only to bear a considerable tension as the weight descends, but also to pull up the carrying apparatus, with any instruments attached to it, when the weight has been left below. The shock of its impact against the bottom, even at a depth of 3 miles, can then be distinctly recognized by a practised hand; and as a line of the required strength can be made small enough to run out very easily, its vertical direction can be pretty well secured, even at great depths, if the operation be carried on by an officer of ability and experience. For work of this kind, a steam vessel has a great advantage over a sailing vessel; since the former can be much more readily kept directly over the line of vertical descent, so as to obtain that true "up-and-down" sounding which is required for the correct estimation of the depth.

The nature of the bottom is ascertained in ordinary shallow water sounding by the examination of the small sample that may adhere to a lump of tallow introduced into a hollow at the bottom of the plummet. But for deep sea soundings it is desirable to employ some arrangement, whereby a larger sample may be brought up without any admixture of tallow; and for doing this, various contrivances have been devised. When the depth does not exceed 1,000 fathoms, so as to permit the use of an ordinary cylindrical deep-sea lead, weighing 100 lbs., which can be pulled up again by the line, nothing is more simple and effective than a conical cup attached beneath this, having a circular lid so fitted as to fall down and close it when an upward movement is given to the lead. For if the cup should penetrate into sand or mud, it fills itself with this before the lid falls down; while subsequent closure of its mouth prevents its contents from being washed out, while the lead is rising to the surface.

During the sounding voyage of the Bulldog, an apparatus was devised by Dr. Wallich, which, as having been subsequently much employed by Swedish explorers of the deep sea, merits special notice. This is constructed somewhat on the plan of a bullet mould; two hemispherical cups, which are kept apart while the apparatus is descending, being brought together by a spring which comes into action when the sinker detaches itself on reaching the bottom, so that a sample of the mud or sand into which they may have penetrated is inclosed between them. This "Bulldogmaskinen," as it was termed by Prof. Sars, has been very effectively used for obtaining, not merely samples of any deposit covering the sea bed, but also specimens of the animal life which it may support. It is obvious, however, that the information it can afford in regard to the latter must be very limited in comparison with that obtained by the use of the dredge; since the forceps can only inclose what happens to lie between them at the spot which they strike.

The sounding instrument now preferred in the British service is known as the "Hydra" apparatus; having been devised by Capt. Shortland, of her Majesty's surveying ship Hydra. It consists of a strong tubular rod, furnished with valves that open upwards, so as to allow the water to stream through it freely in its descent, while the mud or sand into which the tube is forced on reaching the bottom, is prevented by their closure from escaping This is loaded with sinkers; which are masses of iron, each weighing 100 lbs., having the shape of a cheese, with a perforation in the middle for the passage of the rod. One, two, or three of these sinkers may be hung upon it, in such a manner as to rest securely on their support while the apparatus is descending, but to fall off as soon as the rod strikes.

In the recent Porcupine expedition, the 100 lbs. deep sea lead, with a conical cup, was employed for sounding, when the depth was not supposed to exceed 1,000 fathoms. For soundings between 1,000 and 1,500 fathoms, the Hydra apparatus with 2 sinkers was employed; and for depths greater than 1,500 fathoms, 3 sinkers were used. The line to which these were attached was specially made for the purpose, of the best Italian hemp; and although not thicker than an ordinary lead pencil, it bears a strain of 1,200 lbs. It was allowed to run out as fast as the weight would carry it down, a moderate strain being kept upon it; and was reeled in by the donkey-engine provided for working the dredge.

The following particulars of the deepest sounding taken in the expedition will be interesting; since, though not the deepest on record, it is one of the deepest yet made which is thoroughly reliable, having been taken with the most perfect appliances, and managed by an officer of the greatest skill and experience, to whose practised hand the shock of the arrest of the weight at the bottom was distinctly perceptible, though this took place at a depth of nearly 3 miles.

The whole time occupied in the descent was 33 min. 35 sec.; and the rate at the end was about $\frac{1}{3}$ of the rate at the commencement, the retardation being on the whole very regular. The reeling-in, which required great caution in order to avoid putting an undue strain on the line, its friction resistance being much greater than the weight it carried, occupied 2 hrs. 2 min. The pressure exerted by the water of the ocean upon whatever is submerged in its abysses, may be readily calculated when the depth is known. The weight of a column of sea-water, 1 in. sq., is almost exactly a ton for every 800 fathoms of its height; and consequently the pressure upon the bottom at 2,435 fathoms depth is rather over 3 tons upon every sq. in. This, however, has but very little effect upon the density of the water; for the compressibility of water is so slight that even the pressure just mentioned would certainly not reduce it by $\frac{1}{40}$ of its volume, or produce an increase in its density equalling the difference between salt and fresh water. The popular notion therefore, that a mass of iron or lead, thrown into the sea would encounter so rapid an increase in density of the water through which it sinks, that the deeper strata of the liquid would equal, or even exceed, the metal in density, and would thus hold it in suspension or even buoy it up, is altogether unfounded.

Fathoms.	Time.		Fathoms.	Time.	
	Min.	Sec.			
100	0	45	1,300	1	23
200	0	40	1,400	1	32
300	0	45	1,500	1	32
400	0	55	1,600	1	33
500	0	50	1,700	1	37
600	1	00	1,800	1	47
700	1	09	1,900	1	47
800	0	59	2,000	1	47
900	1	22	2,100	1	49
1,000	1	15	2,200	1	55
1,100	1	21	2,300	1	59
1,200	1	21	2,435	1	92

Not less unfounded are the statements that have been put forward upon professedly scientific authority, as to the effects which such pressure must exert upon any substances, whether mineral or organic, that may be exposed to it. Thus it has been asserted in an "Advanced Text-Book of Geology," that "at great depths, sand, mud, and all loose *débris* will be compressed and consolidated;" as if these substances were being squeezed in a Brahmah press, which should force out all their liquid, and bring their solid particles into the closest possible contact. The fact, now ascertained beyond all doubt, that sand or mud retains its ordinary condition at a depth of nearly 3 miles, under a pressure

of more than 3 tons on the sq. in., is perfectly accordant with the law of fluid pressure; for as such pressure acts equally in all directions, it will be exerted just as much in forcing in water between the solid particles as it is in pressing these particles together; and thus an equilibrium being uniformly maintained, the loose sand or mud of shallow water would remain absolutely unchanged in its condition, to whatever depth the bottom might subside. The same principle will be hereafter shown to apply to the case of animals whose bodies are composed of solids and liquids alone; such animals being able to "live, and move, and have their being" under the enormous pressure just mentioned, in virtue of its uniformity of distribution. The case is quite different, however, in regard to substances containing air; for this, under great pressure will either be forced out, or be reduced to extremely small proportional dimensions, its place being taken by liquid.

Thus it has happened that a boat having been dragged down by a whale to great depths, the wood of which it was made sank in the water like a stone, and this, not only when it was first recovered from the sea, but for a long time afterwards. And in like manner, not only the bodies of air-breathing animals, but those of fish provided with swimming bladders, would undergo great changes in size and form when submerged to great depths, owing to the extreme reduction in the bulk of their cavities.

ON ARTIFICIAL STONE AND VARIOUS KINDS OF SILICA.*

By The Rev. H. HIGHTON, M.A.

From "The Building News."

Silica is found in various forms more or less soluble. Some kinds can only be united with akalies in the heat of a glass furnace; other kinds can be dissolved under a high pressure and after a considerable lapse of time by solutions of alkalies; other forms, again, to which the author particularly wished to call attention, can be dissolved under proper precautions, even in the cold. Natural silica of this kind was exhibited both from Germany and England. By means of this soluble silica artificial stone can be formed harder than any natural stone except the very hard granites and primitive rocks. The process is as follows:—

A concrete is made with any good hydraulic cement. When this is dry it is steeped in an alkaline solution of silica, in which is placed a quantity of free silica. The following chemical process then takes place:—The lime in the concrete extracts the silica from the solution, leaving the alkali free, which immediately attacks the free silica and conveys it in its turn to the concrete. This process goes on continually till the lime in the concrete is saturated with silica. By this process, within a week the strength of the concrete is increased from 50 to 150 per cent., and by a longer continuation of the steeping the strength is still more increased.

As the alkali acts only as a carrier of the silica, it is used over and over again; and it is in this that the economy of the manufacture consists.

The following is the comparative resistance to a crushing force of several kinds of stone:—

	Per. sq. inch. lb.
The Silicated Concrete or Patent Victoria Stone	6441
Aberdeen Granite	7770
Dartmoor Granite	6993
Peterhead Granite	6216
Yorkshire Landing	5851
Stafford Blue Brick	4032
Portland Stone	2426
Bath Stone	1244

The stone formed in this manner has been tried as a pavement in the busiest part of Cheapside, and in many other parts of London, and for steps, lintels, sills, etc., in many parts both of this kingdom and abroad, as well as in India.

The whole of the stone in the new warehouses, 27 S. Mary Axe, is made in this manner.

As a cheap, strong stone, when manufactured on a large scale, it is likely to

* Abstract from a paper read before the British Association, Liverpool Meeting, Section B.

supersede natural stone, except where the latter is very cheap and abundant.

In localities, as on the Thames, where there are facilities for obtaining good hydraulic cement and hard broken stone, it can be manufactured at a much lower cost than Yorkshire or other stone can be procured.

COMPRESSION AND TRANSMISSION OF AIR THROUGH LONG PIPES.

Mr. Horace H. Day, of Bloomingdale, N. J., proposes to utilize the waste power of natural waterfalls by employing it in the compression of air, and forcing it through tubes of such length as may be required to reach the engine or motor by which power is to be applied.

Mr. Day has conceived the bold plan of thus employing a small fraction of the enormous store of power at Niagara, and transmitting to Buffalo, 20 miles distant, for the use of manufacturers.

The preliminary experiments by which it was sought to determine the feasibility of such a plan were tried lately at Bloomingdale by Mr. Wm. S. Henson, C. E., of Newark.

The following is Mr. Henson's report :

MR. HORACE H. DAY: DEAR SIR,—In accordance with your request, I submit to you the result of my observations of your experiments at Bloomingdale, in the compression and transmission of air through pipes as a means of utilizing power at long distances from its source. In order to carry out your demonstrations and experiments, you have laid 2 miles of pipe; that is, two separate and distinct pipes of 1 mile each, both of lead, and $1\frac{1}{4}$ inches diameter (inside measure); 1 mile reaches from a mill situated about $\frac{3}{4}$ of a mile off, and in its course passes over the side of a mountain, which I rightly estimated at about 300 ft. high, and over very rough, uneven ground, the mile being completed by passing partly round a field adjoining your place, and then terminating in your mill. The other mile of pipe starts from your mill, passes twice round your premises and an adjoining field, and then runs about 500 ft. along one side the field and back again to complete the mile, terminating at your mill. Both pipes run over very rough, uneven ground, and are full of crooks, bends and angles—the weight of the pipes having caused them to assume the profile of the ground. There is an air-compressor and a receiver for each pipe; each air-compressor consists of a horizontal cylinder, 5 in. diameter, and provided with suitable valves at each end, and a piston driven by a crank and pulley, like a common, double-acting steam engine reversed and used as a double-acting pump; each receiver consists of a cylinder 30 ft. long and 16 in. diameter, made of boiler-plate and strongly riveted. One compressor and receiver is located at the mill, $\frac{3}{4}$ of a mile away, and is driven by the water-wheel there; the other compressor and receiver are situated upon your own premises, and the compressor is driven by a small turbine wheel, of about $2\frac{1}{2}$ horse power. Each compressor pumps the compressed air directly into its own receiver, situated near it, whence it flows into the connecting pipes, which both terminate at your place, where there is an excellent vertical cut-off steam engine of A. K. Ryder's patent, having an 8″ cylinder, 10″ stroke, estimated at 17-horse power, built by the Albany Street Iron Works, New York. The cut-off is admirable for its simplicity and effectiveness, and the design and workmanship of the engine reflects great credit upon the constructors. The pipes are so arranged in connection with this engine, that it can be driven by either compressor alone, or both connected, or the air from the compressor, situated $\frac{3}{4}$ of a mile off, can be sent through the 2 miles of pipe in succession.

The theoretical power required to drive one of these compressors 100 revolutions per minute, when compressing to 75 lbs. above the atmosphere, or 6 atmospheres altogether, is estimated at 5.87-horse power, plus the friction. This calculation is based on the well-known law of Mariotte, viz.: that with equal temperatures the pressure is inversely as the volume, as although there is generally a considerable increase of temperature in the act of compressing air, yet with good compressors this heat can be so nearly all ab-

sorbed that Mariotte's law will practically hold true.

In 1837 a series of experiments were made by order of the Italian Government (preliminary to the commencement of the Mont Cenis tunnel) on the resistance of tubes to the flow of air through them, one of the principal objects being to ascertain the laws which govern the variations of resistance, when the velocities of flow and the diameters of tubes are varied, as well as to determine the practicability of using compressed air in driving the tunnel. From the results of these experiments the 3 following laws were deduced, as reported by Professor Barnard (see his able report on the Paris Universal Exposition for 1867, republished by Van Nostrand, New York):

1st. "The resistance is directly as the length of the tube;"

2d. "It is directly as the square of the velocity of flow;"

3d. "It is inversely as the diameter of the tube;"

and your experiments, as far as they have gone, have confirmed the substantial truth of the first and third propositions, and demonstrated the existence of another law of vast importance to the practical transmission and application of the power of compressed air through pipes for long distances, viz.: that the loss per cent. of the whole power from friction in transmitting a given mass, or, more properly speaking, weight of air, through a pipe of given dimensions, diminishes inversely in a geometrical progression, the divisor or ratio being 2 for every increase of 10 lbs. pressure, as may be seen by inspection of the following table, obtained from actual experiment. The pressure gauges used in these experiments are the same kind as those ordinarily used on steam engines, and made by E. H. Ashcroft, the dials being marked at every 5 lbs., and the intermediate divisions measured and read by the eye alone. The pipe used is one of the two mentioned above, one mile long and one and a quarter in. diameter, commencing and terminating on your premises; the air compressor being one situated on your place. The pressure gauges being located both in the same room, could be readily compared with each other, the first gauge being placed near the beginning of the mile of pipe, and the second gauge near the end of it; and the readings are as correct as I could measure them by the eye alone. The water power driving the compressor was so regulated as to deliver the same weight of air at each experiment, that is, 120 cylinders full per minute, 5 in. diameter, and 20 in. long.

The velocities are calculated from the volumes due to the pressures, according to Mariotte's law, and the pressure at the second gauge was obtained by partially closing a valve attached to the end of the pipe until the desired pressure was obtained, and at which both gauges remained constant, without further adjustment, some 15 or 20 minutes. The second table below was obtained from the first by calculation up to 100 lbs.

Number of strokes of Compressor per minute.	1st Gauge Pressure, in pounds.	2d Gauge Pressure, in pounds.	Velocity at beginning of pipe, in feet, per second.	Velocity at end of pipe, in feet, per second.	Mean velocity per second.	Loss from friction in pounds.	Loss per cent. of the whole power delivered by Compressor.	Percentage of loss calculated from last column.
120	22	10	21	32	26	12	54.50	54.50
120	28	20	18 06	22 6	20.6	8	28.57	27.25
120	35.25	30	16	17 8	16 9	5.25	14.89	13.67
120	43.25	40	13.66	14.33	13 99	3.25	7.51	6 83
120	51 75	50	12	12.26	13.13	1.75	3.38	3.41

SECOND TABLE.

	61.03	60		10.66		1.03		1.70
	70.596	70		9.38		.596		.852
	80.341	80		8.46		.341		.426
	80 192	90		7.62		.192		.213
	100.100	100		6.93		.100		.106

It will be observed that if the percentage of loss in the eighth column, commencing at the top, is divided by 2, it will give 27.25 in the 9th column, 2d line, and that again divided by 2 gives 13.67; and if this process is continued in succession, it ends with 3.41 in place of 3.38, as got by experiment, and by continuing the same process the last column of the second table was obtained. It will be also observed that a very slight variation in the readings of the gauges would make the differences between the eighth and ninth columns in the first table.

These results, while demonstrating the necessity of a high degree of compression—say from 85 to 100 lbs. per in.—to reduce the loss resulting from transmission through long distances of pipe, are at the same time extremely favorable, as for transmitting great quantities of power the air requires to be considerably compressed, and both objects are thus gained by high compression.

These experiments, made alone by myself with great care, to discover the cause of observed variations, are entirely confirmed by reference to your records, extending through several months, and made before we were looking for, or were conscious of, any law on the subject.

In response to your request for the elements necessary for the transmission of 5,000-horse power from Niagara Falls to Buffalo (about 20 miles), using your magnificent power of 206 ft. fall, I suggest the utilization of 185 ft. of this fall by the direct compressing power of a column of water acting as a ram, without the intervention of water wheels or the friction of cylindrical compressors with moving pistons, because by the use at *that point* of such compressors, you absorb the heat generated in the act of compression, and avoid the loss from friction by piston or cylinder, and all the wear and tear of ponderous water wheels.

This direct acting hydraulic pressure, working in one sense as a ram, may be made to develop any amount of pressure desirable, and, taking into account the cost of pipes and other considerations, I would suggest that the pressure should not be less than 80 lbs. or more than 100 lbs. per square inch; and a pipe of 42 in. in diameter would transmit from Niagara Falls to Buffalo a column of air compressed to 100 lbs., with a velocity of 10 ft. per second, and a loss from friction of tube, for the whole distance, not exceeding 1 per cent. of the power transmitted, and deliver for us over 5,000-horse power of cold air. I should recommend, however, a pipe of 36 in. diameter, which should deliver a column of air at 100 lbs. pressure, and 14.33 ft. per second terminal velocity, and give a full 5,000-horse power of cold air, worked expansively, at a loss by friction not exceeding 5 per cent. for the 20 miles.

Great unnecessary loss would result if common non-expanding steam engines were to be used to work off the power; and the more perfect the compressors for condensing the air, and the greater the excellence of the steam engines, the better.

You propose to construct the pipe with boiler plate $\frac{1}{4}$ in. thick, and paint it both inside and out with a strong, indestructible varnish, whereby it will not only be rendered absolutely air-tight, but will be perfectly protected from corrosion.

Before closing my report, I will only refer to your experiments for expanding the compressed air, at the moment of its use, through the steam engine. As you are taking out patents for your discovery, I need only remark that, in my judgment, it will contribute in no small degree towards that growing appreciation everywhere manifested by the intelligent public for compressed air as a motive power.

Professor Charles S. Storrow, an eminent engineer of Massachusetts, and the commissioner employed by that State to proceed to Europe to examine the works there going on, and especially that for tunnelling the Alps, to discern the practicability of finishing the Hoosac Tunnel by compressed air, in the closing part of his report, introducing a minute description of the process practised at Mont Cenis, uses the following expressive language, which is so just and appropriate that I may be excused for quoting it here:

"For the construction of the tunnel, the great instrument in the hands of the engineer is compressed air—and what an instrument it is! By its aid they furnish air for respiration, wind to drive away vapors, power to run machines. They eject water to play against the rocks, produce cold to temper the atmosphere, and

heat by a blast of the forges near the entrances. Thus air, wind, power, water, cold, heat, can be applied, and precisely where they are wanted. This sounds like fable, but it is a literal truth."

W. S. HENSON.

THE MECHANICAL WORK OF WALKING.

Translated from Weisbach's "Ingenieur und Maschinen Mechanick." (Vol. 2.)

In walking on a horizontal path the whole body turns about the point of contact (C) of the advanced foot.

If h is the height (D E) through which the centre of gravity rises, l the length of the leg (C A, C B), s the length of the step (C H, C R), we have $DE = \frac{AD^2}{2AC}$, or $h = \frac{s^2}{8l}$. Let G = the weight of the man, Q = the weight of his burden; then the work

$$L=(G+Q)\,h=\frac{(G+Q)s^2}{8\,l}$$

and the force

$$P=\frac{L}{s}=\frac{(G+Q)s^2}{8\,l}$$

Suppose $l = 3$ ft. and $s = 2$ ft., then the force

$$P=\frac{2\,(G+Q)}{8.3}=\frac{1}{12}(G+Q)$$

If Q = 0 and G = 140 lbs.
$P=\frac{1}{12}G=11.67$ lbs.

Hence the work done in making a horizontal step, s, is equal to that done in rising vertically to a height $1\frac{1}{2}\,s$; and the effort required is equal to that of lifting a weight of 11.67 lbs.

In walking up an inclined plane (Fig. 2) of inclination a, if β = the angle between successive positions of the leg, we find

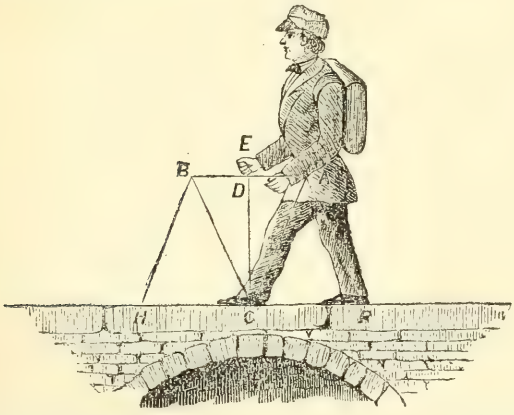
$$DE=h=CE-CD=CE\,(1-\text{Cos. A C D})=$$
$$l\left[1-\text{Cos.}\left(a+\frac{\beta}{2}\right)\right]=l\left(1-\text{Cos. }a\,\text{Cos.}\,\frac{\beta}{2}+\text{Sin }a\,\text{Sin}\,\frac{\beta}{2}\right)$$

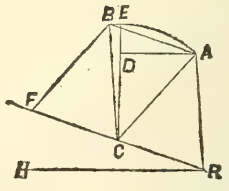
and approximately, for a small stepping angle a,

$$h=l\left(1-\text{Cos}\,\frac{\beta}{2}\,\text{Sin }a\,\text{Sin}\,\frac{\beta}{2}\right)$$
$$=l\left(\frac{s^2}{8\,l^2}+\frac{s}{2\,l}\,\text{Sin }a\right)=\frac{s}{2}\left(\frac{s}{4\,l}+\text{Sin}\,a\right)$$

The mechanical work of each step:

$$L=(G+Q)\,h=(G+Q)\left(\frac{s}{4\,l}+\text{Sin }a\right)\frac{s}{2}$$





The mean force:

$$P=\frac{1}{2}(G+Q)\left(\frac{s}{4\,l}+\text{Sin }a\right)$$

In walking down hill a is negative, and

$$P=\frac{1}{2}(G+Q)\left(\frac{s}{4\,l}-\text{Sin }a\right).$$

In this case if $\text{Sin }a=\frac{s}{4\,l}$, the work is zero.

If $l = 3$ and $s = 2$, we have
$\text{Sin }a=1\frac{1}{6}=0.1666.$
$\therefore a = 9\frac{1}{2}°$, the angle of easiest descent.

If $a=\frac{\beta}{2}$ the work of walking up is

$$P=\frac{(G+Q)s}{4\,l},$$

and $a>\frac{\beta}{2}$ *i. e.* $>\frac{s}{2l}=\frac{1}{3}$;

that is, if $a > 19°$, we have

$$P=(G+Q)\,\text{Sin }a.$$

ON THE EXPLOSIVE ENERGY OF HEATED LIQUIDS.

By W. J. MACQUORN RANKINE, C.E., LL.D., F.R.SS. L. AND E.

From "The Engineer."

1. *References to Theoretical Investigations.*—In contemplation of the revival of the application (first invented by Perkins) of the sudden evaporation of highly heated liquid water, in order to propel projectiles, it may be useful to give a summary of the rules for calculating the utmost theoretical effect of a given fluid when so employed, under given circumstances. For the theoretical deduction of those rules from the laws of thermodynamics I have to refer to two independent investigations, made respectively by myself and by Clausius; the former published in the "Philosophical Transactions" for 1854, pages 160 to 162; the latter in "Poggendorff's Annalen" for 1856. The rules themselves, with some tables of their results, having reference to the bursting of steam-boilers, have also been published in the "Transactions of the Institution of Engineers in Scotland" for 1863-4, vol. vii., page 8; and in the "Philosophical Magazine" for 1863, vol. xxvi., pages 338 and 436. In a subsequent communication I propose to consider the case when the fluid passes into the state of vapor before its admission into the gun.

2. *General Formulæ for all Fluids.*—Suppose a closed boiler to be entirely filled with a fluid in the liquid state at a certain absolute temperature t_1. Let the absolute temperature t_2, being lower than t_1, be the boiling point of that fluid in a boiler open to the atmosphere. Let a given mass of the liquid be made to escape from the boiler, and to perform work by expanding partly or wholly, as the case may be, into the state of vapor, and driving a solid body (such as a bullet) before it, until its pressure falls to that of the surrounding atmosphere, and its absolute temperature (consequently) to t_2. Then the energy exerted by that mass of fluid is equivalent to the raising of its own weight to the height given by the following equation:—

$$U = K t_2 (n - 1 - \text{hyp. log. } n). \quad . \quad . \quad (1)$$

in which K denotes the dynamical value of the specific heat of the fluid in the liquid state; and $n = \frac{t_1}{t_2}$ the ratio in which the initial absolute temperature is greater than the final. Moreover, the following formula gives the excess of the space filled by each unit of weight of the fluid at the end of the expansion, above the space filled by an unit of weight of the liquid:

$$s = \frac{K \text{ hyp. log. } n}{\frac{dp_2}{dt_2}} \quad . \quad . \quad . \quad . \quad (2)$$

in which $\frac{dp_2}{dt_2}$ denotes the rate at which the pressure of saturation varies with the boiling point, at the final temperature.

Absolute temperatures are given, as is well known, by adding 461.2 deg. to temperatures on the ordinary Fahrenheit's scale, or 274 deg. to temperature on the ordinary Centigrade scale.

3. *Formulæ for Water.*—For water the values of the co-efficients in the formulæ are as follows very nearly:

$$K t_2 = 520{,}000 \text{ ft.};*$$

$$\frac{K}{\frac{dp_2}{dt_2}} = 18.38 \text{ cubic feet per lb.};\dagger$$

or to a rough approximation about 1,100 times the volume of the hot liquid water. Hence we have the following formulæ for water; energy of the explosion in foot pounds per pound of water:

$$U = 520{,}000 \ (n - 1 - \text{hyp. log. } n) \quad . \quad . \quad (1A)$$

Space swept by the explosion, or final volume of the water and steam in cubic feet to the pound.

$$s = 18.38 \text{ hyp. log. } n \quad . \quad . \quad . \quad . \quad (2A)$$

or in terms of the volume of the liquid water,

$$1100 \text{ hyp. log. } n, \text{ nearly}, \quad . \quad . \quad . \quad (2B)$$

4. *Examples.*—To illustrate the results of the preceding formulæ, the two following examples are given, in which the values assumed for n are respectively 2 and $2\frac{1}{4}$. The pressures corresponding to the temperatures given by those ratios are not known by experiment. The pressures given in the following table of results are calculated on the assumption that the formulæ which are found to be accurate up to the limits of experiment, are applicable

* 153,500 metres, nearly.
† 1.147 cubic metres per kilogramme, nearly.

also to temperatures far beyond those limits; hence, those pressures are to be viewed as in a great measure conjectural. This affects the safety of the boiler and of the gun; but not the energy of the explosion, nor the final volume of the fluid; for these two quantities vary with the temperature only.

	Example I.	Example II.
Ratio of initial to final absolute temperature	2 ..	2¼
Final absolute temperature, Fahr.	673 2°..	673.2°
Final absolute temperature, Cent.	374° ..	374°
Initial absolute temperature, Fahr.	1346.4°..	1514.7°
Initial absolute temperature, Cent.	748°..	841.5°
Initial temperature, ordinary scale, Fahr.	885.2°..	1053.5°
Initial temperature, ordinary scale, Cent.	474° ..	567.5°
Energy of the explosion, foot pounds per pound of water	159,562..	228,189
Final volume—cubic feet per pound of water and steam	12.74..	14.9
Final volume—ratio to initial volume of water, nearly	760 ..	890
Conjectural absolute pressure in boiler, pounds on the square inch	7,180 ..	13,345
Ditto, ditto, in atmosphere	490 ..	908

The values of the energy of the explosion in the two examples agree very nearly with the least and greatest values found by experiment for the energy of the explosion of 1 lb. of gunpowder; hence the examples may be taken as showing the conditions which must be fulfilled in order that 1 lb. of heated water may produce the same effect as 1 lb. of gunpowder. In both examples the initial pressures are so high that the only safe form of boiler is a coil of tube of small bore compared with its thickness. This was the form employed by Perkins.

5. *Expenditure of Heat.*—The expenditure of heat required in order to produce the elevation of temperature of each unit of mass of liquid from the temperature of the feed to that at which it escapes from the boiler, is expressed in dynamical units as follows:

$$H = K\,(t_1 - t_3) \quad . \quad . \quad . \quad . \quad . \quad (3)$$

in which t_3 denotes the absolute temperature of the feed. Let this latter temperature bear the ratio n^1 to the absolute temperature of the atmospheric boiling point; then we may express the same expenditure of heat in the following manner:

$$H = K\,t_2\,(n - n^1) \quad . \quad . \quad . \quad . \quad (3A)$$

and for water, the value of this in foot pounds per pound, is very nearly

$$H = 520{,}000\,(n - n^1) \quad . \quad . \quad . \quad (3B)$$

The value of n^1 for water ranges in ordinary cases between 0.7 and 0.8. Assuming it to be 0.75, the expenditure of heat in the two preceding examples is found to have the values given in the following table:

Heat expended.	Example I.	Example II.
Foot pounds per pound	650,000	780,000
Units of evaporation	0.873	1.047

The difference between the quantities in the first line and the values of the energy of explosion, are the quantities of heat which go to waste with the escaping steam and water after the explosion, viz.:

Waste heat.	Example I.	Example
Foot pounds per pound	490,438	551,811

6. *Efficiency of the Explosion.*—This term may be used to express the ratio borne by the energy of the explosion to the whole expenditure of heat. Its value is as follows:

$$\frac{U}{H} = \frac{n - 1 - \text{hyp. log. } n}{n - n^1} \quad . \quad . \quad . \quad . \quad (4)$$

And it is to be observed that this value depends solely on the ratios borne to the absolute temperature of the atmospheric boiling-point, by two other absolute temperatures, viz., that of the feed water, and that of the liquid just before it escapes from the boiler. In the two examples the values of the efficiency of the explosion are respectively;

Example I.	Example II.
0 245	0 293

7. *Remarks.*—The preceding formulæ all proceed on the assumption that the specific heat of the liquid is sensibly constant. This is not perfectly accurate, for the specific heat of every liquid increases slowly with the temperature. The effects of that increase are shown in the original theoretical investigations referred to at the commencement; but for practical purposes it is unnecessary to take them into account.

The formulæ also take no account of the retarding effect of friction on the bullet, nor of the inertia of the air which it drives before it in the barrel of the gun, nor of the loss of energy which may take place through the abstraction of heat from the water by the metal of the barrel; those being quantities which can be determined by direct experiment alone.

The initial temperatures assumed in the examples have been chosen so as to make the explosive energy of the water nearly equivalent to that of an equal weight of gunpowder. By choosing a lower initial temperature the initial pressure may be moderated; but the explosive energy of a

given weight is at the same time diminished; and a greater mass of water must be used in order to obtain a given amount of energy, thus increasing the proportionate quantity of energy which is lost in propelling the explosive material itself, as the following section will show:

8.—*Efficiency of Projection.*—This term may be used to denote the proportion which the energy of the bullet at the instant of its leaving the gun bears to the whole energy of the explosion.

Let m denote the ratio which the mass of the bullet bears to the mass of the explosive material; M the ratio which the whole mass that recoils bears to the mass of the explosive material; v the velocity of the bullet at the instant when the action of the explosion ceases, so that the energy of the bullet at that instant, *per unit of mass of explosive material*, is $\frac{m v^2}{2 g}$; then, neglecting fraction and the inertia of the air, etc., it can be shown that the energy of the explosion of an unit of mass of explosive material is disposed of in the following manner:

$$U = \frac{v^2}{2g}\left\{ m + M\left(\frac{2m+1}{2M+1}\right)^2 + \frac{1}{2}\left(1 - \frac{2m+1}{2M+1} + \left(\frac{2m+1}{2M+1}\right)^2\right)\right\} \quad . \quad . \quad (5)$$

On the right-hand side of this equation the first term $\frac{m v}{2 g}$ is the energy of the bullet.

The second,

$$\frac{M v_2}{2 g}\left(\frac{2m+1}{2M+1}\right)^2$$

is the energy of the mass which recoils.

And the third,

$$\frac{v_2}{6 g}\left(1 - \frac{2m+1}{2M+1} + \left(\frac{2m+1}{2M+1}\right)^2\right)$$

is the energy of the projectile motion of the products of explosion, at the instant when they cease to act on the bullet. Hence the *counter-efficiency* of projection, being the reciprocal of the efficiency, or in other words, the ratio in which the whole energy of the explosion is greater than that of the bullet, is expressed as follows:

$$c = 1 + \frac{M}{m}\left(\frac{2m+1}{2M+1}\right)^2 + \frac{1}{3m}\left\{1 - \frac{2m+1}{2M+1} + \left(\frac{2m+1}{2M+1}\right)^2\right\} \quad . \quad (6)$$

from which it appears that the energy lost through the projection of the products of explosion is greater, the greater the proportion $\frac{1}{m}$ borne by the mass of the explosive material to that of the bullet, and that when the proportionate weight M of the recoiling mass is very great, that lost energy is approximately equal to the fraction $\frac{1}{3m}$ of the energy of the bullet.

For example, let $m = 8$, and $M = 1000$; then the three terms of the counter-efficiency of projection have the values shown in the following equation to three places of decimals: $c = 1 + 0.009 + 0.041 = 1.050$; that is to say, the energy lost in the recoil is 0.009, and the energy lost in projecting the products of explosion 0.041, of the energy of the bullet; the latter being by far the more important loss; and hence it is desirable not to increase unnecessarily the comparative weight of the explosive material.

FRENCH ENGINEERING BEFORE THE WAR.

From "The Builder."

The science and the practice of the engineer are receiving daily illustration in the course of the present war. The scientific corps of the army have attained an importance which is not undue, but which is certainly unprecedented. Even that great engineer, captain, and legislator, who commenced his career as a lieutenant of artillery in the regiment of La Fère, never contemplated the dominant importance which his favorite arm was to assume in the combinations of the strategist. Everywhere we see the same lesson. In the field the victory remains to the best ordered and best handled artillery. Courage and even tactical genius count for nothing before superior batteries. The tide of war spreads round the great railway lines, overflowing its banks, like the Nile, but still fed by the steady main stream of communication. The relation between the number of days that a fortress can hold out, and the number and calibre of the siege guns, is becoming

more clearly than ever a matter of elementary arithmetic. The opinion laid down by no less eminent an authority than Julius Cæsar, that Fortune tells for much in war, must now be checked and modified by the axiom that Science tells for more.

While the progress of war thus taxes the utmost efforts of human skill, it, in some instances, ruthlessly destroys the noblest public works. At a time when so many of the engineering monuments of France are in danger of being swept away, it is unusually instructive to glance at some of the latest triumphs attained by the civil engineers in that country.

In regarding the historic progress of mechanical skill, it is natural to consider that the most simple inventions are those which we owe to the infancy of science. Moreover, complexity, accompanied, it may be, by striking elegance of arrangement, and giving evidence of patient and exhaustive thought, characterizes the greater part of modern improvements in mechanism. But for the primary application of science to practice we must, for the most part, cast our glances back to a period when the human mind, if less full of knowledge than at present, evinced a more perfect mastery over the elements at its command. For the origin of the pendulum, indeed, we can only look back for a comparatively short period of time. But the invention of the pendulum closely accompanied the first sound investigation of the laws of falling bodies. In the same way the invention of the barometer, and the complete mastery of the theory of the pump, accompanied the discovery of the pressure of the atmosphere. A method of raising water, yet more simple than the pump, is associated with the name of Archimedes; and there is no reason to doubt that the problem of the reflection of light, and the concentration of radiant beams, was practically solved by that great philosopher.

With regard to some of the simple utensils of human art, their origin is lost in obscurity. Some tradition of the earliest use of fire is preserved in the legend of Prometheus; but the form is not such as to make the information which it hides readily intelligible to ourselves. Ancient Semitic history is silent on this grand question; although it refers to the discovery of wine. Among the tools familiar to our hands, while the circular saw is barely a century old, and the ribbon saw not a tenth of that age, the saw itself is of immemorial antiquity. It may be considered that, like the knife, the axe, the arrow-head, and the wedge, it represents a natural subdivision of that series of original sharp flint cutting instruments which we know to have preceded the use of metallic tools. The scissors and the shears, on the contrary, must have been invented after metallurgy had made some advance, and probably after the discovery of iron. The invention of the bellows is probably coeval with that of the forging of metal, and must have preceded any successful attempt at smelting, except in the rudest manner, and from the richest ore. It is not generally known that the wandering tinkers of Italy—men who bear the traces of gipsy blood—make use of a form of bellows entirely different from that common to the Northern European nations. The gipsy bellows consists of a pair of bags of skin, which are closed by 2 straight pieces of wood. A loop on each of these bars serves for the insertion of the thumb and finger. A wind bag is worked alternately by each hand; the arm being lifted, and the finger and thumb opened, to admit the air, and then the finger and thumb being brought together, the slit is closed, the arm depressed, and the air is thus forced through a pipe into the fire, now on the right, now on the left of the blower; who squats on the ground between these primitive implements. The "blast and counter blast" of the smith's forge, referred to by the oracle of Amphiaraus as to the discovery of the grave of Orestes, is far more appropriately referrible to this Italic form of bellows than to our Teutonic valved chamber.

If the present inventions from which all mechanical improvements have sprung are for the most part so ancient and so fruitful, no ordinary degree of merit must attach to any modern discovery which can apply, for the first time in human history, a well-known principle to a well-known want which it is fully competent to supply. A practical step of this nature has been taken by M. Beau de Moulin, an engineer-in-chief of the French Corps of Engineers of Ponts et Chaussées; and we consider it to be one demanding the most serious attention, and deserving the widest fame.

Every engineer and every architect who has had the responsibility of building a large bridge, is aware of the anxiety attendant on the easing and striking of the centres. The need of providing firm reliable points of support on which great weight may be safely brought, but which may be readily movable at will, is not confined to bridge building. Among the many cases in which it is desirable to resist such a power at command may be mentioned the launching of vessels, and, generally, the dealing with enormous weight. The tendency of our recent practice, in this respect, has been in favor of the use of hydraulic power. This, however, is both costly and cumbrous, and requires an amount of previous preparation which consumes much time, and has interfered with the application of a method, the power obtained by which is no secret.

M. Beau de Moulin has availed himself of one of the well-known properties of sand—of that mechanical fluidity of its particles, with which we are all familiar in the hour-glass. So simple and so beautiful is the application, that one hears of it for the first time with a positive blush of shame that it should have been left to our own time undiscovered.

The method to which we refer is the simple and beautiful plan of throwing the bearings of the ribs of a centre upon sand, contained in iron cylinders, from which it is allowed slowly to escape at will.

Each principal is supported upon round props, fitting as pistons into cylinders filled with fine dry sand. These cylinders are of sheet iron, $\frac{1}{32}$ in. thick, 1 ft. high, and 1 ft. in diameter. At 2 in. from the bottom each cylinder is perforated with $\frac{3}{4}$ in. holes, which are stopped by common corks. To ease the centring it is only necessary to remove the corks. The sand immediately flows from each hole, forming a cone outside the cylinder. The formation of this cone arrests the further escape of the sand, and therefore stops the gradual descent of the piston which follows on the escape. As the sand is swept away, the issue recommences, and may be thus continued, or arrested, at will, till the centring is entirely detached from the masonry. By carefully regulating the issue from the holes, the utmost delicacy of movement may be imparted to the centre. It may be eased at the same moment in each part, or either end of any principal may be made to descend with greater or less rapidity. The inventor, indeed, claims the power of graduating movement by millionths of an inch; and it is not easy to say what is the practical limit of delicacy attainable by the process. Not the slightest shock is caused by a mode of operation which appears to be not only theoretically but practically perfect. The idea would have done honor to the most illustrious name in the history of human science.

The use of this admirable method of replacing the maul of the carpenter, and the wedges of our early bridge builders, was tested on an arch of very unusual proportions. It was desired to construct a bridge over the Seine, in Paris, to connect the Rue du Louvre with the Rue de Rennes. The bridge had to span one of the locks of the Canal de la Monnaie. The springing of the arch, therefore, had to be clear of the canal walls, while the crown was kept down by the necessity of preserving the level of the roadway. The rise of the arch, thus determined, was about $\frac{1}{18}$ of its span, or 6 ft. 11 in. in 124 ft.

The architectural harmony of the situation demanded that the new bridge should be constructed of stone. With a wise perception of the fact that it would not do to risk experiments in the midst of Paris, M. Vaudray, the engineer, took the precaution of building an experimental arch, before venturing to throw such an unprecedented piece of masonry over the Canal de la Monnaie.

The spot selected for the experiment was the quarry of the plains at Soupes, 60 miles from Paris, on the Bourbonnais Railway. One abutment was formed by the natural face of the rock, the other by a block of masonry, 27 ft. high, 49 ft. deep, and of the same width as the arch, viz., 12 ft. It was built of rubble masonry, well bonded, and laid in Portland cement mortar, one part of cement to three parts of sand. Its construction occupied 20 days. The arch itself was built of 77 voussoirs of cut stone, the depth of the key-stone being 2 ft. 8 in., and the ring gradually increasing in depth to 3 ft. 7 in. at the springing. The beds and joints were carefully dressed and laid in Portland cement mortar, two parts of sand to one of cement. The thickness allowed to each

joint was $\frac{3}{8}$ in. The joints next the skew-back were not flushed until after the completion of the ring, having been kept open by means of fir wedges.

The arch was allowed to rest for four months on the centring, which was then eased by allowing the sand to escape from the cylinders. The effect which was produced by the slackening of the centres was watched with the utmost attention. In an hour daylight was perceptible between the soffit of the key-stone and the lagging. In two hours the centring had entirely left the arch. It was then found that the crown had come down 6-10ths of an inch, and that the joints of the skew-back on the built abutment side had opened 7-100ths of an inch. After the lapse of three days the arch was observed to have sunk 7-100ths of an inch more. It was then loaded with a weight of 360 tons, disposed over the whole surface of the roadway, an operation which occupied 13 days. The crown was brought down by the weight 3-10ths of an inch more.

Since that time nothing has stirred. The arch has been tested by allowing a weight of 5 tons to fall upon the roadway from a height of 18 in., without causing the slightest injury to the bridge. The triumphant execution of a masonry arch of such unprecedented proportions is a credit to French science and practice. It is unnecessary to insist on the accuracy of workmanship that is requisite for such a structure, or to point out how much the engineer was indebted to the method employed for striking the centres of his arch.

Reports on the great French engineering works have been published under the auspices of the Minister of Agriculture, Commerce, and Public Works. It is to be feared that we have seen the last of these reports that will be issued for a considerable time. An unrivalled collection of models, plans, and specifications, explanatory of bridges, viaducts, reservoirs, docks, and tunnels, illustrates the state and progress of civil engineering in France. It is much to be desired that so good an example should be followed in our own country. The records of our great public works, and the detailed information gained during their progress, should not be left to the enterprise of publishers, or even to the paternal vanity of engineers. The recent public works of London alone, including the Thames Embankment, the main drainage, the river bridges, the metropolitan railways and termini, are such as to entitle Great Britain to an eminent position among engineering nations, and should be recorded with such literary and graphic luxury as befits their historic importance.

The chief works of the Old World during the present quarter of a century are the tunnel under Mont Cenis, and the canal through the Isthmus of Suez. Both these important works owe their origin, if not their entire conduct, to French enterprise. It would be unworthy of the profession of the civil engineer, as carried out in this country, to entertain either jealousy or regret at the great progress which our professional brethren on the Continent have made since the date of the introduction of the railway system into France. Yet it is well that it should be borne in mind how much of this actual advance is due to the impulse, not only intellectual, but financial, of this country. English engineers not only wrought out the railway system in this country, but introduced it on the Continent. Their experience and advice were eagerly sought, and not only so, but the financial support which their names were once accustomed to command, proved to be a *sine quâ non* for the start of many of these undertakings, which now form so important a part of the Continental system of communication. In France, indeed, we have been far more fairly dealt with than in other Continental countries. The highly educated and thoroughly organized corps of the engineers of the *Ponts et Chaussées* lost no opportunity of acquainting themselves thoroughly with the best results of our English expenditure. What the civil and mechanical engineers of France have accomplished during the last 15 years would seem incredible to those who are not practically acquainted with the subject. In the manufacture of iron, the most decided progress has been made. The rails which were supplied from the French *usines* for the Chemin de Fer du Midi were of such a quality that they often snapped beneath the mere weight of the ponderous locomotives that a French house was then beginning to supply. A fitter, with a hammer and a cold chisel, could cut through any one of these

rails, with ease, in twenty minutes—that is to say, an English fitter. And so difficult proved the task of supplying even these inferior rails in adequate quantity, that a number of miles across the Landes of Bordeaux, for which the French factories were under contract to supply the rails, were actually laid with Barlow's rails, sent out from this country, to the great economy of time and increase in durability of way, no less than of safety to the public.

How thoroughly this state of things has been changed it is unnecessary to say. In fact the only part of the case that now would be thought incredible is the statement of what formerly existed. In other parts of the Continent the normal hunger for English gold has led to frequent applications, down to within a comparatively recent time, for the services of the civil engineers of this country. Too often, however, has the transparency of the device become evident only a little too late, and the men whose opinions were welcomed as oracles while the subscription list was open, were asked by what right they interfered, when all the available funds had been insured.

While rendering a full meed of tribute to the energy, perseverance, and original constructive genius that have opened a navigable highway from the Mediterranean to the Red Sea, we must not shut our eyes to the fact that the information which has been given to the public as to the actual procedure of the work has always been carefully *filtered*, not to say manipulated. It is necessary to bear this in mind, now that all we have of the undertaking is an account of the tonnage of the vessels that make use of it. But we have been given to understand, from very reliable sources, that the anticipations of Mr. Stephenson as to the deposit of sand in Port Said are fully confirmed. The actual differences of depth between two consecutive soundings, taken a few weeks apart, are so great that we do not like to mention them without being at liberty to publish the details of the surveys. To maintain a line of navigable channel, in place of a deep and commodious basin, is, we are told, the only present idea of the administration; and even this will tax the utmost energies of the dredging apparatus. Of course, this statement will be denied; but that will have little effect on the minds of English readers. We believe that it is strictly correct.

With regard to that other main link in the chain which was intended to connect London with Calcutta, English enterprise has not disdained to compete with the owners of the mules so familiar to the Alpine tourist, for the temporary traffic over Mont Cenis. The snows of the Alps have only occasionally arrested the trains of M. Fell, and he has shown himself able to contend with the minor difficulties of inclination and of traction. But the eyes of all the engineering world will be strained to watch what sort of a junction will be effected by the French and Italian engineers in the bowels of the Alps. Of the seven miles and 1,007 yards between Modane and Bardonnèche we were told some time since that the Italian half was completed, and that the Italian engineers were straining their efforts to meet their French *confrères* as far over the frontier—or rather as far under the frontier—as possible. The success of the compressed air machinery has been admirable. We confess that we look with more anxiety to the accuracy of the level than to that of the line. Unless the utmost care has been taken, on each face, to take no levels without the precaution of using perfectly *even sets*, disturbance may have been caused by the varying attractive powers of the different strata, which no means exist for checking. When even it is effected, the meeting of the two halves of the tunnel will be one of the most critical and interesting facts in the entire history of civil engineering.

It is melancholy to see how the rapid progress of our professional brothers in France—a progress that we have had repeated opportunities of watching with our own eyes, since Mr. Locke first went over to teach Frenchmen how Englishmen made railways—is arrested by the mailed hand of invasion. Not only must progress in civil works be entirely suspended, but maintenance must in many instances become all but impossible. What can now be the traffic over the Mont Cenis? What the sources of income for French railway shareholders? The unexpected, and, to our mind, extremely improvident readiness with which a new French loan has been grasped in the City, is no offset to the real depreciation of all property in public works in France. Actual destruc-

tion of works, although that may be reckoned by millions, not of francs, but of pounds sterling, is not the most serious evil; for the invaders must, for their own service, substantially repair most of the damage caused in order to arrest their march. While any debatable land exists between France under German power, and France under no power at all, havoc is likely to be made there. But the sudden check to the whole circulation of national and of international traffic is a calamity such as we have never witnessed since the Stephensons first matured the invention that we trusted would peacefully bind together the civilized world in a girdle of iron.

IRON AND STEEL NOTES.

IRON RAILS *vs.* STEEL-TOPPED RAILS.—In an appendix to the second Annual Report of the Board of Railroad Commissioners of Massachusetts, we find the following valuable letter from Mr. Abram S. Hewitt;

"NEW YORK, Dec. 15th, 1870.

"We have now reached definite conclusions in regard to steel-topped rails. We have made an inspection of every rail laid prior to January 1, 1870, on the Erie Railroad of our make, whether steel-topped or iron. You will bear in mind that the steel used for the heads is pulled, and not cast or homogeneous steel. It is necessarily of low temper, in order to secure a weld with the iron.

"It is harder and has more tensile strength than iron, but it is softer and has less tensile strength than cast-steel, even of the low grade (so far as carbon is concerned) used for Bessemer and other steel rails.

"A *priori*, it might be expected that the durability of this material would be intermediate between iron and steel—that is, more durable than iron and less so than steel. It is also intermediate in cost, and the problem to be solved is, whether iron rails, or iron rails with puddled-steel tops, or cast-steel rails are more profitable with a given volume of business.

"I think that it is now demonstrated that with a small business, where iron will endure from 12 to 15 years, iron is the more economical material; with a larger business, where iron will endure 5 years, the puddle-steel tops are the cheapest; and with a larger business, where the average life of an iron rail does not exceed 3 years, steel rails are the cheapest. Our experience is mainly confined to the Erie Railway, which comes within the third category. In arriving at this conclusion we assume that good iron rails cost $75 per ton, puddled-steel headed rails $90 per ton, and cast-steel rails $105 per ton.

"Now for the results on the Erie Railroad, premising that we have made no inspection of the cast-steel rails laid down, and can therefore institute no definite comparison with them, but we are told that the failures during the time covered by our report have been comparatively insignificant, and we believe that the report is true.

"The total number of rails delivered, prior to the date when the inspection began was 46,276 rails; of these we found in track 45,716 rails, and 560 rails were not found. Some of these 560 rails may have been overlooked in the track; but in making up the results, we have assumed them to have entirely failed, thus making the worst case for the durability of the rails.

"Again, the rails were made by several different methods of piling, some of which have proved to be better than others; and the result would therefore have been more favorable if all the rails had been made by the method which experience has proved to be the best.

"Of the total number of 46,276 rails, there were puddled-steel tops, 36,238; iron rails, 8,103; doubtful marks, 1,935; by "doubtful marks," is meant, that the inspector could not determine to which class the rails belonged.

"The average time of wear in track of these rails is 13 months; and this average time is equal for the steel-topped and the iron topped rails; so that the comparison is perfectly fair as to the time, but as a general rule the steel-topped rails were laid in places where the wear is greatest. To that extent the comparison is more favorable to the iron rails than it should be.

"The results of the inspection are as follows:—

Steel-Topped Rails.

Good rails in track	34,867	
Imperfect rails in track	833	
Failures, including missing rails	538	
Percentage of failures	1.5	per cent.
Percentage defective in track	2.3	"
Total percentage failed and defective	3.8	"

Iron Rails.

Good rails in track	6,934	
Imperfect rails in track	593	
Failures, including missing rails	576	
Percentage of failures	7 1	per cent.
Percentage of defective in track	7.3	"
Total of failed and defective rails	14.4	"

Doubtful Rails (whether Steel or Iron).

Good rails in track	1,738	
Imperfect rails in track	103	
Failures, including missing rails	94	
Percentage of failure of rails	4 9	per cent.
Percentage of defective rails	5.3	"
Total percentage of failed and defective	10.2	"

"These results go to show that these doubtful rails were mostly iron rails.

"For general conclusions, the result may be stated, that on the Erie Railroad, where the volume of business is enormous, and from the width of the gauge, the weight of the cars and locomotives is far greater than on narrow gauge roads, and the rate of speed is fully equal to any other American road.

"Fourteen four-tenths per cent. of iron rails made in the best possible manner failed in 13 months' wear, at which rate all the rails will be worn out in 90 months or 7½ years, making the average life of the rail 3¾ years.

"Three eight-tenths per cent. of puddled-steel topped rails failed, at which rate all the rails will be worn out in 342 months, equal to 28½ years, making the life of the rail 14¼ years, if we assume that the failures will go on at the same rate and that the rate of failure will be uniform for each kind of rail.

"I consider therefore that the results on the

Erie Railroad have fully justified the policy of substituting steel-topped rails for iron rails, at an extra cost of $10 per ton (in their case), and if *all-steel* rails could be had at an extra cost of $10 per ton over the cost of these steel-topped rails, I believe that a still greater economy would result.

"This conclusion still leaves open the question whether a cast-steel top may not be advantageously applied to an iron rail, but I do not consider this point of much practical importance, because I believe that all-steel rails can be made as cheaply as iron rails with cast-steel tops, and all difficulty in reworking old steel rails has disappeared with the full success of the Martin process for melting steel scrap on the open hearth of a reverberatory furnace.

"The practical result of the renewal of the eastern portions of the Erie Railway with steel-topped rails has been to reduce the requirements for new rails from 2,000 tons per month, when Mr. Gould assumed the management of the road, to about 600 tons per month at the present time. This requirement may, however, be expected to increase rather than to diminish from this time henceforth; but being reduced to so small a quantity I have advised Mr. Gould to have the Trenton works prepared for the manufacture of all-steel rails for future renewals, whereby I anticipate that the life of the track will be doubled.

"The policy adopted of getting to all-steel, by means of puddled-steel tops, by which the old rails were all made available and the outlay kept within moderate limits, is most suggestive for roads doing a large or an increasing business; and is probably the only practicable method of arriving at the ultimate desideratum of an *all-steel* track, without taxing the resources of the railway corporations beyond their immediate strength to bear.

"Faithfully yours,

"ABRAM S. HEWITT."

VERY great agitation characterized the iron market in Great Britain upon the reception of the warlike note from Russia upon the Black Sea question. The firm stand taken at first by the English Government, impelled the belief pretty generally that war was inevitable. Such an event would have resulted in a great disaster to the manufacturing interests of England, but the heaviest blow would have fallen upon the iron manufacture. Apart from the injury inflicted upon trade by the operation of a disturbed condition of the finances of the nation, which, of itself would have been of a serious character, Russia has, for a number of years, been one of England's best customers for iron, ranking second to this country only. The last five years have witnessed extraordinary efforts on the part of Russia to extend her railway system, and while some of the iron and steel requisite thereto has been manufactured at home, by the aid of heavy customs duties the rails for the purpose were nearly all obtained in England and Belgium. In the month of September of this year there were exported from Wales to Russia, 30,109 tons of rails, and for the nine months ended September 30th, 193,809 tons, against 196,671 tons in 1869, and 69,927 tons in 1868, or nearly 25 per cent. of the total exportation of rails from Great Britain. It is not surprising, therefore, that a feeling akin to a panic prevailed in Wales upon the announcement of the Russian note. The Franco-German war had been exercising a depressing influence on the trade, and rail-makers had hoped that a renewal of engagements with Russian buyers in the spring would do something toward restoring the trade to a fairly prosperous condition. This will not depend entirely upon the manner in which the Black Sea question shall be settled.

The Glasgow pig iron market was likewise affected by the same influence. Prices had recovered several shillings a ton from the lowest point, reached after the heavy decline which followed the breaking out of the war between France and Germany, when the new difficulty set in, effectually dispelling brighter anticipations, and confirming the stagnation of the trade. Pig iron warrants fell as low as 50s. 3d., but prices have recovered a little within a week.—*Bulletin of Am. Iron and Steel Association.*

RAILWAY NOTES.

LOCOMOTIVE STATISTICS.—*Michigan Central.*—The following is the report of the general average of performance of locomotives on all divisions of the road for the month of November, 1870, as made by A. S. Sweet, Locomotive Superintendent:

Number of freight cars drawn one mile	2,694,695
Equal to cars drawn over entire line	9,488
Number of freight cars drawn one mile in October	2,653,671
Equal to cars drawn over entire line in October	9,358
Number of miles run to 1 pint of oil	13.84
" " " 1 cord of wood	32.64
" " " 1 pint of oil in October	13.44
Number of miles run to 1 cord of wood in October	34.05
Average number of miles run per ton by coal-burning engines	37.37
Average number of miles run to one ton of coal in October	39 56
Average of freight trains, cars	23.26
Average size of freight trains in October, cars.	22.76
Number of gallons of oil used	2,397
Number of cords of wood used	5,549
Number of tons of coal used	2,366
Number of miles run by passenger trains	78,427
" " freight trains	127,994
Number of miles run by passenger miscellaneous trains	18,299
Number of miles run by passenger training engines	40,755
Total	265,475

Illinois Central.—The report of S. J. Hayes, Superintendent of Machinery of the Illinois Central Railroad, for the month of October, 1870, affords the following:

Passenger trains	112,475
Freight	302,559
Construction, etc	14,861
Switching	53,063
Total	482,958

The cost per mile run was:

For oil and waste	0.83 cts.
For fuel	7.33 "
For engineers and firemen	5.99 "
For cleaning	1.07 "
For repairs	9.01 "
Total	24.23 cts.

Cost per mile run, in cents:

Passenger engines	16.80 cts.
Freight engines	27.05 "
Construction engines	14.87 "
Switching engines	19.50 "

Average number of miles run to

Pint of oil	13.07
Ton of coal	34.83

179 locomotives made mileage during the month. This report is for 974 miles operated. Nine locomotives have had general, or thorough repairs, and seven are undergoing repairs.—*Railroad Gazette.*

THE SHENANDOAH VALLEY RAILROAD.—The preliminary surveys and estimates for the proposed Shenandoah Valley Railroad are completed and are embodied in a report from the Engineer-in-Chief, W. W. Wright.

The total length of road is 233 miles; the cost per mile is estimated at $30,000, making a total of $6,990,000.

Of the country traversed and the prospective business, Mr. Wright says:

"The magnificent Valley of the Shenandoah, ranging from 30 to 40 miles wide, and extending from the Potomac river to and beyond the southern terminus of our road, is so well and favorably known that an extended description of its resources is superfluous. No richer agricultural region is to be found in the whole country, and roads as expensive as ours have been constructed in other sections for the accommodation of an agricultural business alone no greater than will be commanded by our line. But in addition, we pass for a long distance through a mineral region of almost unsurpassed value. Iron ore of the best quality and in great abundance is found contiguous to our road, and even with the present difficult and expensive means of transportation, it is manufactured to a considerable extent, and with profit. With railroad facilities for transportation to market, there is no section of the country that can manufacture iron with larger profit than the Shenandoah Valley. As an evidence of this, the principal manufacturer there says, "give us a railroad, and we do not need a protective tariff to enable us to compete with foreign iron in the market." Possessing such advantages as this valley does, can there be any doubt that the iron interests will have great development as soon as the railroad is completed, and furnish a heavy item of business to the road?

"Then the thousands and thousands of acres of white oak, white pine, and other valuable timbers, that are now almost worthless, will, with railroad facilities for transportation, at once have such a market value that lumber to a large extent will be manufactured and shipped over the road to the many points that can be supplied more cheaply from this source than any other.

"Not only for the purpose of cutting up this timber, but for any other kind of manufactories, the Shenandoah river furnishes as fine a water-power as can be found anywhere. The volume of water is ample and constant—the river being from 200 to 300 ft. wide and 6 to 8 ft. deep—and the fall at the rate of 5 to 7 ft. per mile. Our line in its general course adheres so closely to the river that it will be easily accessible to the manufacturing establishments that will spring up all along the route, and thus a large and valuable source of business will be created and constantly extended.

"There are various other important items of business that will come to our road which the limits of this report prevent me from naming in detail, but there is one which I ought not to omit. The Valley of the Shenandoah contains some of the most celebrated natural curiosities in the country—conspicuous amongst which are Weyer's Cave and the Natural Bridge—and the adjacent mountain ranges have a world-wide celebrity for the abundance, variety and medicinal value of their Mineral Springs. The travel to and from these popular places of resort will furnish no insignificant revenue to the road.

"From my knowledge of the business of other railroads, I am satisfied that the *local business alone of the Shenandoah Valley is amply sufficient to furnish a good paying business to a railroad that can be constructed for what ours is estimated to cost.* But in addition to this we have another important source of business already created and ready to our hands in the railroad connections that we make. Fortunately for our road, though unfortunately for the interests of the Valley, the construction of railroads heretofore has been *across* the Shenandoah Valley. Starting from the Potomac river, we cross in succession with our line the *Baltimore and Ohio*, the *Winchester and Potomac*, the *Orange, Alexandria and Manassas*, the *Chesapeake and Ohio* railroads, and intersect with the *Virginia and Tennessee Railroad.* These five cross-lines will become in reality feeders to our *Great North and South Line*, which it requires no great gift of prophecy to see will become the great connecting line between the South and South-west and the northern centres of population and trade.

"With such a prospective business there can scarcely be a doubt of the value of your enterprise, and it is fortunate that this is so well understood and fully appreciated by those who have it in charge, that they are resolved to proceed promptly with the work of construction."

THE NEW MINING LOCOMOTIVES.—The Baldwin Locomotive Works have had on exhibition for the last three days two mining locomotives, ordered for the Wilkesbarre Coal and Iron Company's collieries in the third anthracite coal region. Mr. Parrish wishes to find some substitute for the mule as a carrier in the mine. During a strike or other suspension of work, a large stud of mules is a great expense. A locomotive costs nothing when it is doing nothing, and if well cared for does not grow old. Another outlay is saved in the item of drivers. One man suffices to drive a locomotive; and a few couplers to handle an entire train. The fire-box is square and deep, and so little stoking is required, that the fire door need not be opened more than four or five times during the entire day. While the locomotive was standing on the track in the shop, the steam gauge indicated 120 lbs. pressure in the boiler, and yet the engineer had laid a damper plate over the chimney hole. Had the chimney remained open the safety-valve would have deafened the shop. It seemed difficult to explain this excellent draft; but it was an evident fact. The machine was run across the floor at various speeds, started with ease, and stopped in the space of a foot or two. There was an appearance of perfect docility about it, which relieved us from all suspicion of accidents underground.

On examining the working gear, this little locomotive appeared to be as staunchly built and well finished as any passenger engine, but was entirely

without ornament. The wheels were necessarily small, but heavy, with a broad, flat thread, and very light flange. The two cylinders, 9 in. in diameter (inside) by 12 in. stroke, lie under the front end of the boiler. The piston rods play between groups of 4 square slide rods, and a simply adjusted linkmotion works just forward of the fire-box. The connections are of course inside, on the cranked axle of one of the two pairs of drivers (of 30 in.), which are the only wheels. The fire-box and low platform overhangs behind. As coal is always at hand, no coal space is needed, and the water-tank is folded over the top and sides of the boiler, acting as a jacket, and feeling quite hot to the hand.

This tank holds 190 gallons, and the whole engine, with fuel and water, weighs nearly 15,000 lbs. The makers guarantee that it shall haul, under all circumstances, with wet and dirty rails, on a level, 340 gross tons; on a 60 ft. gradient, 80 gross tons, and on a 100 ft. gradient, 50 gross tons. Under favorable circumstances it will of course do more.

The fire-box platform is covered with a light wagon-top roof to guard the engineer's head. The extreme height is 5 ft. 4 in.; extreme width, 5 ft. 1 in.

Several engines, somewhat similar to these, have been constructed in Pittsburg, and used in the mines of that neighborhood, giving satisfaction. These are somewhat simplified; but not to such an extent as to interfere with their being taken readily to pieces, examined, or repaired. It is needless to say that they are made with conscientious care, and made strong, to bear rough usage at the hands of ignorant or thoughtless persons.—*United States Railroad and Mining Register.*

ORDNANCE AND NAVAL NOTES.

New Field Guns.—An experimentnl 16-pounder muzzle-loading field gun on the Fraser principle is now in course of construction at Woolwich. It is designed for a competitive trial with a bronze gun, with which it is to correspond in weight, length, bore, rifling, weight of projectile, and charge of powder. The weight is to be 12 cwt., the bore 3.6 in., weight of projectile 16 lbs., and the charge of powder 3 lbs. The rifling will be in three grooves, on a pattern recently adopted. The only difference between the two guns will be in the nature of the metal, and in the contour of the piece. The Fraser gun is already in hand, and the other will soon be commenced. The former will consist of a steel tube, forming in itself a perfect gun, but reinforced for about half its length in the rear portion with a jacket of coiled wrought iron. The bronze gun will simply consist of that metal, cast in the desired form.

The two guns being thus made on exactly the same pattern, with the bare exception of the external contour, it would seem that until wear and tear produce a difference the competitive pieces must give very similar results, unless there is some diversity in the charge of powder or the projectile. If the bronze gun will bear its charge of 3 lbs., there can be no doubt that the gun of steel and iron will bear a heavier charge. In the latter case we should look for increased range, a flatter trajectory and greater precision. But so far as we can learn at present, the charge of the Fraser gun is to be kept down to the capability of the bronze gun. The competition, therefore, is of a limited character, one gun being allowed to do its best, whilst the other is kept below its power.

The muzzle-loading Fraser guns of 3 in. bore, which, after lying by for some time, have lately been rifled, and now called 9-pounders. In former days they would have been ranked as 12-pounders. There are about sixty of these guns. In weight and bore they correspond to the Indian gun; but they are quite capable of doing duty as 12-pounders, while it is tolerably certain that the bronze gun would be found unfit for the latter purpose, although the Indian gun corresponded in bore to the old 12-pounder. It is said that the Indian gun gives better results with a 9-pound shot than with one of 12 pounds. The question, we presume, is simply one of proportion between powder and shot. We may get the right proportion either by reducing the weight of the shot or by increasing the weight of the powder charge. Of course we are speaking within certain limits. But we would ask, why is it that the bronze gun cannot take the charge proper to a 12-pound shot, whereas the gun of wrought iron and steel, having the same weight and calibre, is able to do so?

The urgent necessity for increasing the power of our field artillery is rendered painfully evident by recent events on the continent. Are we, then, wise to use a metal which—weight for weight and bore for bore—gives the lesser power as compared with the built-up gun of steel and iron? As for breech-loading, it is sufficiently clear that more is lost than gained by employing it in our artillery, valuable as it undoubtedly is when applied to small arms. For the rifle and the mitrailleuse, breech-loading is invaluable. But the rapidity of fire which breech-loading confers on small arms disappears in its application to field artillery; while, whatever other merits it may possess, a field piece on the breech-loading principle is peculiarly liable to be disabled by some derangement of its apparatus, the complicity of which is also likely to be very embarrassing in the excitement of action.

With regard to the use of steel in the service guns, it may be needful to observe that this metal is not relied on as an element of strength. In our great guns steel serves as a lining, giving the necessary surface, and offering a better resistance than iron to the erosive action of gunpowder. The necessary strength is obtained by the use of coiled wrought iron which envelops the steel tube. In the experimental 16-pounder the forward part of the gun is of bare steel, the tube protruding from the wrought iron envelope. In a gun of this size, the steel is thought sufficient by itself towards the muzzle, where the strain is least, but the wrought iron is added towards the breech where the strain becomes severe. There are facts on record which show the necessity of being very guarded in the use of steel where the force of gunpowder is concerned,

Passing from the consideration of steel and iron to that of bronze, it seems curious that the latter should receive any degree of preference as a material for our field guns, seeing that bronze is discarded at the two extremities of the scale, namely, the rifle and the heavy gun. At the present time we need, as far as possible, to combine in our field artillery the accuracy and range obtainable on the principle of the rifle with the greatest practicable weight of shot. Not that mere weight of projectile is of itself a special advantage in firing against

troops; but this weight may be made to represent enhanced destructiveness in the effect of explosive shot. In number of guns our field artillery is lamentably weak. So far, this gives us an opportunity for introducing new and effective weapons corresponding to the era in which we live. The lure of "cheapness" must be steadily resisted on this point. The great cost of our field artillery is not the guns, but the men and the horses. It has recently been shown in these columns that the yearly cost of a troop of horse artillery is at the rate of £6,000 per gun. On such a foundation we ought not to rear a superstructure simply "cheap." Moreover, nothing is cheap in war that is not effective, and effectiveness demands something more than mediocrity. Positive inferiority is certainly to be avoided. But if we are coming into the field with bronze guns, the War Office can scarcely be said to have learned aright the story of Sedan.—*Standard.*

In the recent great sortie made by the French from Paris, General Ducrot brought into action one of those new engines of destruction to the invention of which the present war has given so great an impetus. This is an armor-plated locomotive, furnished with two powerful mitrailleurs, also protected by armor, and originally intended for the railway bridge at Point du Jour, whence it was to throw bullets on to the heights of Meudon. This novel machine, which weighs altogether only some six tons, has been manufactured at Cail's, the well-known mechanical engineer of Paris, to whose establishment the city is so much indebted for the extraordinary efforts that have been made to supply it with cannon and other means of defence. The Prussian invasion has certainly contributed a great deal to develop the inventive talents of the French ; for hardly a day passes without some new implement of destruction being submitted to the Government of National Defence. Under the spur of defeat they have produced the Marekderberg mitrailleur, firing 250 balls a minute, and the Montigny, firing 480, as well as the Durant steam mitrailleur, which discharges no less than 4,500 in the same space of time, and the Frauche use, or "mower, "which is said to operate without noise, smoke, or fire, to have a range of from 500 to 600 yards, and to cost only 35f. with all the necessary apparatus for firing 300,000 projectiles ; so that, if every bullet really had its billet, the French by employing this weapon might rid themselves of the whole of their enemies for something less than 100f. In addition to the above, many novel descriptions of shells have also been proposed, if not actually tried, among which are the Gaudin fire-bomb, the improved Menestrol shell bombs emitting suffocating vapors and so on.—*Pall Mall Gazette.*

We understand that the French are fully alive to the fact that their system of field artillery is inferior to that of the Prussians, and that they are making strenuous efforts to improve their material. In fact, the sole merit of the French system is its simplicity. Their field piece, as a muzzle loader, compares favorably, both in mechanism of gun and in simplicity of ammunition, with the more complicated breach-loader of the Prussians. Here, however, the superiority ends. In accuracy, in flatness of trajectory, and in hard hitting, the Prussian field piece is by far the more powerful weapon. Much of this is due to the calibre. The French *canon raye de* 4 is a bronze muzzle-loader converted into a rifled gun by grooving the old 6-pounder smooth-bore, the calibre of which is 3.4 in. The calibre of the Prussian steel 4-pounder is, however, only 3.1 in.; its projectile, consequently, although of the same weight, is of less sectional area than that of the French gun. The Prussian shells are, therefore, better adapted to overcome the resistance which the air opposes to all bodies moving through it, and the result is that they lose less of their original velocity, and, consequently, hit harder at a distance. It is easy to prove that the atmosphere offers resistance to bodies passing through it, and that the amount of this resistance depends in a great measure on the velocity or rate at which the body may be moving. If we take a book, open it, and, having placed one page upright, pass it forward, the page will shut by the resistance of the air. In walking in the open air on a clear calm day we experience very little resistance from the atmosphere : a canter on horseback, however, produces a refreshing current, and we feel a breeze, as it were, against the face ; while on the same day, if we put our head out of a railway carriage, we are obliged to press down our hat firmly to prevent its being blown off. To all appearance, however, there is no wind. We can understand, therefore, the enormous resistance which a shot must experience, travelling as it does ten times as fast as the fastest train. This resistance, moreover, is considerably influenced by the shape of a shot. As the bluff collier stems the current with difficulty as compared to the taper yacht, so the dumpy, ill-proportioned projectile meets with a greater resistance than one formed on more scientific principles.—*Globe.*

ENGINEERING STRUCTURES.

International Industrial Exhibition. — The proposed building for the proposed International Industrial Exhibition is thus described in a little pamphlet containing the prospectus of the Company:

The site of the Palace of Industry embraces four full blocks (forming an area of about 23 acres) uncut by any streets, situated between Ninety-eighth and One Hundred and Second streets, the Third and Fourth avenues, and accessible by the horse cars of the Third, Fourth, Second and Madison Avenue Railroad Companies; and also by the steam cars of the Hudson & Central, the Harlem, and the New York and New Haven Railroad Companies—all of which will shortly pass its western boundary, on their way to the Great Union Depot.

The position, separated only by a narrow strip of land from the Central Park, is lofty, and commands a beautiful panoramic view on all sides.

The improvements of the vicinity for the ensuing three years will probably increase the value of the property several millions. As an operation in real estate, it is profitable.

This Palace of Crystal is designed to be a marvel of beauty and grandeur, sufficient in extent to accommodate readily 70,000 persons; and it will be arranged as a Repertory of the Art, Science, Invention and Industry of the world. Within its long and lofty halls will be arranged and classified the various products of the earth. Art will display her paintings and her statuary. There will be

gardens, with tropical plants and birds, and fountains; halls where music or lectures can be heard. All these and many other attractions will here combine to teach the intellect and delight the imagination.

There will be no restriction of expenditure, which would mar any of its proposed attractive features.

The building will run around the ground, and be in depth 150 ft., and eight (8) stories high above ground.

There will be a court of eleven (11) acres in the centre.

The court will be covered with glass, and from roof to floor will be about 120 ft.

This court will be used as a Horticultural Garden.

The upper story of the building will be an Art Gallery, with skylight opening through the top.

The width of the Art Gallery will be 150 ft., and the length will be 3,760; or two rows of paintings, which will give 7,520 ft. of wall or space in length, on which to exhibit paintings.

The second story from top will be given free to Artists as studios, or such space of same as may be needed; and a library will be included on each floor.

There will be four Observatories—one at each corner of the building.

THE TEHUANTEPEC SHIP CANAL.—The following is an epitome of the ship canal concession, which passed the Mexican Congress on the 13th of December and has now become a law :—

ARTICLE 1. Authorizes the Tehuantepec Railway Company to construct a ship canal and its appurtenances, in addition to its railway, across the Isthmus of Tehuantepec to connect the waters of the Gulf of Mexico with the Pacific Ocean. The canal is to be of a depth sufficient to pass ships drawing 19 feet of water, and the concession is for 99 years; the Mexican Government to protect the execution, preservation and security of the work.

ART. 2. Explorations and surveys to be completed within 3 years, and plans and profiles to be submitted to the President of Mexico for approval. Work on the canal to be commenced within one year after the plans are approved.

ART 3. Requires a bond from the company in the sum of $50,000 that plans shall be presented within 3 years.

ART 4. The obligations of the company to do the work required may be suspended by a fortuitous case or by *force majeure*.

Provision is made for the proper notices to be given the Government of the removal of the impediments and the recommencement of the works.

ART 5. Right of way free and one-half of the public lands within 5 miles on each side of the canal in aid of its construction.

ART 6. May take private lands for use of company whenever necessary, by indemnifying the owners according to law, but may take public lands and material gratis.

ART. 7. During the construction of the canal the company may import on the Isthmus the materials, machinery, tools, coal, carriages, and other useful articles duty free, and after the canal is completed the company may import, duty free for 99 years, the machinery and hard coals that it may require.

ART 8. For 99 years the Mexican Government will exact no contribution for transit through the canal, nor on the capital invested therein; after that time the works become the property of the Government.

ART 9. After 20 years the Government will be entitled to 20 per cent. of the net profits when dividends are paid to stockholders

ART 10. Tariff and regulations governing the use of the canal and other works to be made by the company and submitted to the President of Mexico for his approval.

ART. 11. The company to build two lighthouses, one on each coast, which are to become the property of the Government.

ART 12. The transit through the canal shall be free to all the inhabitants of the globe. All nations may use it in time of peace for transportation of their troops, munitions and vessels of war; but its entrance shall be vigorously closed to troops, munitions and vessels of war belonging to nations which may be at war with one another or with others.

The canal shall be neutral and open to all nations at peace with the Republic of Mexico, but the transit and other dues shall be increased 25 per cent. on vessels and merchandise belonging to nations having no treaty of neutrality with Mexico with respect to the transit by the canal.

ART. 13 The direction and management of the canal shall belong to the company, but the Government reserves the right to appoint one-fourth of the number of directors, who shall have the same prerogatives as those elected by the stockholders.

The company shall make an annual report the President of Mexico.

ART. 14. The company, though formed abroad, shall be deemed exclusively Mexican, and, if it thinks proper, may form separate companies for the carrying out of its several operations, and may organize said companies either in the republic of Mexico or in the United States, under general or special laws of the place where formed.

ART. 15. All persons now and hereafter engaged in the enterprise are to be regarded as naturalized Mexicans.

ART 16. The restrictions of the previous articles shall not affect differences arising between aliens and stockholders outside of the republic, nor shall the decisions of foreign tribunals affect the provisions of this law nor Mexican interests.

ART. 17. The company cannot transfer, alienate or mortgage the concession, nor the canal and its accessories, without the consent of the Mexican Government, and in no case can it be done to a foreign government, nor can a foreign government or State become a partner in the enterprise. The company may issue and sell bonds and other obligations without the approval of the Government in such amounts and at such prices as it may see fit; and may mortgage the canal and its accessory works to private individuals or associations.

ART 18. The grant shall become null and void:

First—If the surveys and plans of the canal are not made within 3 years.

Second—For not commencing the works within 1 year after the plans are approved by the President of Mexico.

Third—If $1,000,000 are not expended in the first year after the works have been commenced, and $3,000,000 per annum thereafter until the

works are completed, except in case of *force majeure* duly proved.

Fourth—For violating any of the expressed provisions of this law as enumerated.

Fifth—In case of forfeiture of the railway concession.

Six'h—In case of neglecting for 365 consecutive days to keep the canal open for use.

ART. 19. In case of forfeiture of grant the company shall lose the concession, but will retain as its own property, until the expiration of 99 years, the works which it shall have constructed ; but the successors of this company shall have the right to take the same at an appraisement.

ART. 20. All doubts and controversy as to the interpretation or execution of this law will be decided by the competent federal tribunals of the Mexican republic.

ART. 21. The company shall appoint a representative, to reside in the City of Mexico, who shall have power and instructions to treat with the Federal Government and other authorities upon all matters included in the present concession.

NEW BOOKS.

A MANUAL OF THE MECHANICS OF ENGINEERING AND OF THE CONSTRUCTION OF MACHINES, with an introduction to the calculus. Designed as a text-book for technical schools and colleges, and for the use of engineers, architects, etc. By JULIUS WEISBACH, Ph.D., of the Royal Mining Academy of Freiburg. Vol. 1. Translated from the last German edition by ECKLEY B. COXE, A.M., Mining Engineer. New York : D. Van Nostrand.

The superior excellence of this great work on mechanics lies not alone in the fulness with which each and every topic is treated, but also in the thoroughly practical application of deduced principles and formulas.

There are many works on mechanics which afford good mathematical discipline to one who is seeking to gain expertness in the line of independent scientific investigation, or who is desirous of giving that finish to his mathematical acquirements which the standard of modern literal culture requires. Such works accomplish the ends designed without satisfying the demands of him who has adopted the profession of engineering. The technical student and the practising engineer both require not only the conclusion to which the theoretical investigation leads, but the useful application of the result, and the modification of it, which the exigencies of practical life may require.

The student will find in the work before us a logical arrangement of topics, and a progressive gradation of mathematical applications which satisfies his utmost need in the way of mental training ; and the practical engineer may find the formulas deduced and applied in every recognized department of engineering.

It is 24 years since the appearance of the first German edition. The present American work is translated from the fourth German edition, with the advantage over the latter of some emendations afforded the translator by the author.

An introduction to the calculus begins the present volume, and affords the pupil the elementary drill sufficient to follow all the subsequent applications of the higher mathematics in the work.

Then follows a section on the purely mathematical theory of motion, in two chapters, extending over 50 pages, after which follows the physical science of motion in general ; of this section there are 40 pages. The illustrations by diagram (there are more than 50 in these two sections) of resultant motion are most admirable.

The next section treats in 5 chapters respectively of the statics of rigid bodies ; the centre of gravity ; equilibrium of bodies rigidly fastened and supported ; equilibrium in funicular machines; the resistance of friction ; and the rigidity of cordage.

Section 4 is devoted to "the application of statics to the elasticity and strength of bodies." There are 5 chapters also in this section, devoted respectively to elasticity and strength of extension; compression and shearing ; elasticity and strength of flexure or bending ; the action of shearing elasticity in the bending and twisting of bodies ; the resistance of columns to crushing by bending or breaking across ; combined elasticity and strength. This important section covers over 200 pages, and closes the subject of statics of solids.

The dynamics of rigid bodies naturally follows, and beginning with the discussion of the moment of inertia the author applies the analysis to lines, surfaces, and solids, in the most exhaustive manner. This section (5th) includes also chapters on centrifugal force ; the action of gravity on bodies moving in prescribed paths, and the theory of impact.

Section 6th treats of statics of fluids, and, in addition to the more general principles of hydrostatics and aerostatics, elucidates the theory of floating bodies, their buoyancy and stability. The work done by compressed air is the leading topic of the last chapter (4th) of this section.

The dynamics of fluids forms the subject of the closing section of this first volume. It is divided into 9 chapters, treating successively the following topics, the mention of which will sufficiently indicate their important practical bearing : The general theory of the efflux of water from vessels ; the contraction of the vein or jet of water when issuing through orifices in thin plates ; the flow of water through pipes ; resistance to the motion of water when the conduit is suddenly enlarged or contracted ; the efflux of water under variable pressure ; the efflux of air through pipes ; the motion of water in canals and rivers ; the theory of measuring water ; the impulse and resistance of fluids.

This section alone is embellished with 206 illustrations, and it abounds, moreover, with tables of constants derived from experiment that are of the highest value to the hydraulic engineer. An appendix treating of the "theory of oscillations" appears in the present volume, although wanting in the latest German edition, this chapter having been recently written by the author.

When employed as a text-book in our colleges and higher scientific schools much of each section must be necessarily omitted, the work is so voluminous ; but as all of the amplification of a subject by this author is designed to afford aid to the learner, so the student of Weisbach, whether in the school or out of it, is never confused by the extent of the subject or the number of applications. Students who are familiar with algebra and trigonometry may read almost the entire work without the treatise on calculus which begins this volume.

An example of the author's method taken from

the second volume will be found in another place in the present number of the MAGAZINE.

A RUDIMENTARY MANUAL OF ARCHITECTURE, being a History and Explanation of the principal Styles of European Architecture, Ancient, Mediæval, and Renaissance. By THOMAS MITCHELL. London: Longmans, Green, & Co., 1870. For sale by Van Nostrand.

In his preface to this volume, Mr. Mitchell explains that the object he had in view in publishing it, was rather to lead the students on to further research than to attempt any comprehensive scheme of instruction. The latter course would, indeed, have involved far more labor, and expanded the book greatly beyond its present limits, but we doubt that it would have been beyond the capability of the writer. In fact, we read Mr. Mitchell's manual wishing it were something more, yet willingly testifying that he has at least fulfilled the promise contained in the title of his book.

The first chapter is devoted to the early history of architecture, and in this Mr. Mitchell points out that in the various styles of construction peculiar to different countries can be traced out the primitive habits of life of the various races at the commencement of their existence. The first rude habitations which sheltered primæval man—the cave, the tent, the hut of logs—were the foreshadowings of those structures which should in future ages be developed into the lasting monuments of civilization, more enduring than the nations that had reared them. The temples of Assyria and Egypt, massive as the hills, the ruins of the architecture of Greece, bringing more plainly in their decay the first ideas which gave them birth, the light fantastic palaces of the East, all these speak of the outlines of their first types, the rock-hewn shelter, the rough timber dwellings, the skin-covered tents of the hunting, the pastoral, and the agricultural tribes. Tracing the development of European architecture from its rudest outlines to its most finished and harmonious proportions, Mr. Mitchell proceeds to sketch out the progress of the Greek, the Roman, and the Byzantine styles, and to show how the classic rules diverged and extended into the most beautiful and picturesque of all orders, Gothic, with its interminable variation. The larger portion of the book is devoted to this part of the subject, and great credit is due to the author for the skill with which he has selected his information, at once the most valuable and the most concise. Numerous engravings are introduced, well executed and necessary for the illustration of the text, but this latter feature extends throughout the book, and adds greatly to its value. With a chapter on Elizabethan and Debased Gothic, and another on Renaissance, Modern Italian, and Modern Architecture, the manual concludes. We must not omit to notice, however, the appended glossary containing 600 terms, and which will be found of service, although it cannot be regarded as an architectural dictionary. Altogether, Mr. Mitchell's book is entitled to take a first place among the numerous manuals which are now being produced so plentifully.—*Engineering.*

INTRODUCTION TO THE STUDY OF INORGANIC CHEMISTRY. By W. A. MILLER, M.D., D. C. L., LL. D. London: Longmans & Co. For sale by Van Nostrand.

This is one of the useful and carefully edited "Text-books of Science" publishing by Messrs. Longmans. It possesses a melancholy interest as being the last work from the pen of the late Dr. Miller, who says, in the preface, that it is written expressly for beginners; and, in order that they should really understand the statements which it contains, it will be necessary for them to begin at the beginning and to go straight through it. The elements and chemical notation are first clearly explained, and the student is then inducted into the mysteries of atmospheric air, water, carbon, and the other non-metals; the second division being occupied with the metals. More than 250 experiments are described, and numerous wood-cuts given. As a specimen of the manner in which the metals are described, we extract the following:

"Aluminum: *symb.* Al; *Atomic wt.* 27; *sp. gr.* 2.67.—This metal derives its name from alum, of which material it constitutes between 5 and 6 per cent. Its compounds are among the most abundant constituents of the rocks, including felspar, hornblende, and slate. Aluminum may be obtained from cryolite (3 Na F, Al F_3) by fusing it with sodium; but the method usually practised consists in decomposing sodic aluminic chloride (Na Cl, Al Cl_3) by heating it with sodium; an intense action occurs, and the aluminum is obtained in a melted state under the fused sodic chloride—

$$Na\ Cl\ Al\ Cl_3 + 3\ N\ A = 4\ Na\ Cl + Al.$$

Aluminum is a white malleable metal, resembling zinc in color and hardness. It may be rolled into foil and drawn into wire. When struck, it gives a clear musical sound. It melts at a temperature below that needed for the fusion of silver (1023° C.) It preserves its brightness in the air, and is but slowly oxidized at a red heat. Nitric acid attacks it with difficulty, but it is rapidly dissolved by hydrochloric acid, and by solutions of the alkalies, hydrogen being given off. This metal, with about 90 per cent. of copper, forms a golden yellow alloy, called *aluminum bronze*, well fitted for castings."

The various salts of aluminum are then described, and experiments given to prove the correctness of the statements made. The proof sheets were seen through the press by Mr. C. Tomlinson, at the request of Dr. Miller. The book is clearly printed, and is one of the best introductions to inorganic chemistry for beginners with which we are acquainted.—*English Mechanic.*

ELEMENTARY TREATISE ON NATURAL PHILOSOPHY. By Professor A. PRIVAT DESCHANEL, of Paris. Translated and edited, with extensive additions, by Prof. EVERETT, D. C. L., of Belfast. In 4 parts. Part 1—Mechanics, Hydrostatics, and Pneumatics. London: Blackie & Sons. For sale by Van Nostrand.

This translation of Prof. Deschanel's "Traité de Physique" will, we believe, be found extremely useful. An elementary treatise of moderate size on Physics has been long wanted in our schools. Atkinson's translation of Ganot, or Brook's Natural Philosophy, is too expensive for general use, and of smaller books, none, so far as we know, are good. The issue of Dr. Everett's translation in parts at the moderate price of 4s. 6d., will enable it to be largely employed. The engravings with which the work is illustrated are especially good, a point in which most of our English scientific works are lamentably deficient. The present part contains Mechanics, Hydrostatics,

and Pneumatics. The clearness of Deschanel's explanations is admirably preserved in the translation, while the value of the treatise is considerably enhanced by some important additions. Thus, to Deschanel's description of the pendulum is added a short account of the condition of isochronous vibration, moment of inertia, momentum, and kinetic and potential energy. In the section on Pneumatics, Deschanel's extremely good description of the air-pumps of Hawksbee, Bianchi, Kravogl, Geissler, and Deleuil, is supplemented by an account of Sprengel's mercurial pump. It is possible to point out defects, but they are few. The conception of "mass" is always a difficult one for a beginner. Deschanel gives a very clear explanation, which is not reproduced, the term being employed without explanation. Nor do we understand why, instead of Deschanel's statement that the co-efficient of absorption of ammonia in water at O°C. is 1050 (exactly it is 1150), it is said to be only 600. But these are minor defects, and we repeat that we believe the book will be found to supply a real need.—*Nature*.]

A Text-book of Elementary Chemistry, Theoretical and Inorganic. By George F. Barker, M.D., Professor of Physiological Chemistry in Yale College. 12mo, pp. vi, 342. New Haven: Chas. C. Chatfield & Co. 1870.

In this text-book, Professor Barker has rendered a service which cannot fail to be gratefully appreciated by all those whose office it is to teach the principles of chemistry, and especially by those engaged in instructing college or academic classes, where, from the comparatively limited time that can be spared for the study, and in accordance with the educational aims of the institutions, the object is to give the student clear and accurate knowledge of the fundamental principles of chemistry as a science, and its most important practical applications and results, rather than to attempt a technical and thorough mastery of the subject. The latter must be gained in the laboratory, and by months, or even years, of patient labor and study. But in the thorough systematizing of principles and their results, in its admirable nomenclature, in its delicate and precise methods of research, and by the insight it gives into the phenomena of daily experience, chemistry forms an invaluable instrument of intellectual discipline, and its study an indispensable part of a complete education.

A radical defect of most of the text-books of chemistry hitherto has been that the principles of the science have not been presented in a systematic and prominent manner, but have been scattered at hap-hazard in the mass of fact and detail, and so have in a measure been obscured and lost sight of in teaching

This evil, Professor Barker has happily and completely avoided. The first part of the book, about one fourth, is devoted to Theoretical Chemistry, and the subject is developed from simple principles and careful definitions into a clear and definite system. The admirable generalizations of the new chemistry are given with great perspicuity and conciseness, and are illustrated with numerous examples.

The second part is devoted to Inorganic Chemistry, the most important of the elements being discussed in regard to their distinctive chemical qualities, their combinations, and their economic uses. The electrical relations of the elements, a matter of fundamental importance in the new chemistry, are made the basis of the order of treatment in the book, the imperfect and ill-defined classification into metals and metalloids, or into groups formed upon analogies or resemblances, being thus avoided. Copious experimental illustrations of the various points are described, and made intelligible and attractive by numerous cuts.

The treatment of the subjects in this part of the work is marked by the same clearness of description and conciseness of statement as in the first part, and these qualities, as well as the fulness of its matter, render the book most valuable, not merely as a text-book, but also as a convenient manual of reference for the advanced or professional student.

We have only space to add a word respecting the mechanical execution of the book, which in respect to clearness and elegance of typography and handsome press-work is all that could be desired.—*College Courant*.

MISCELLANEOUS.

Sub-permanent Magnetism Experiment.—The following experiment may be interesting or useful to some of your readers. The object of the experiment is to produce, in a few minutes, what Dr. Tyndall has named sub-permanent magnetism; and thus represent to a class *quickly* what is effected by the earth *slowly* in soft iron lying in the magnetic meridian, and subject to molecular disturbance from percussion or other causes.

The requisites for the experiment are—a block of cast-iron (wrought-iron might, perhaps do) slightly magnetized, a bit of soft iron wire, a hammer, and a magnetic needle for testing the wire.

Expt. 1.—Lay the iron wire on the block, and hammer it lightly from end to end, for a few seconds. Presented to the needle, the wire will be found magnetized, showing distinctly strong N. and S. poles, produced by the S. and N. poles of the block.

Expt. 2.—Place the wire *reversed* on the block, *i. e.*, lay the N. pole of the wire on the N. pole of the block, and hammer as before. Tested again by the needle, the wire exhibits its poles reversed.

Expt. 3.—Lay the wire as in Expt. 1, and hammer; the original polarity is restored. Finally, by changing the position of the wire, the pole may be changed and rechanged as long as the wire lasts.

This experiment would seem to represent well the magnetizing action of the earth. The block personates the earth with its magnetism, which is not less comparatively than that of cast-iron. Were the wire to remain for a considerable time lying on the block, it would be magnetized. The hammering effects *quickly*, in the whole wire, that molecular disturbance which is slowly, and piece by piece, produced in great masses of iron standing on the earth. E. Kernan.—*Chemical News*.

The Russians assert that they possess a breech-loading rifle which is far superior in all respects as a military weapon to our Martini-Henry. We understand that our authorities have been made acquainted with this fact from information which has reached them from St. Petersburg.—*Army and Navy Gazette*.

VAN NOSTRAND'S
ECLECTIC
ENGINEERING MAGAZINE.

No. XXVII.—MARCH, 1871.—Vol. IV.

THE FAIRLIE ENGINE AGAIN.

By LOUIS NICKERSON, C. E.

While track is being torn into ribbons so as to be often dangerous, stockholders are grumbling at non-payment of dividends, directors regretting their inability to pay them, and superintendents truthfully excusing themselves because of the non-lasting properties of iron rails and permanent way; hundreds of thousands of dollars are yearly spent to replace the present ponderous engine, the demoniac cause of nearly all damage, yet a few thousands seem too much to inaugurate a fair trial of the Fairlie system (on the score of no experiment), notwithstanding their fair showing in England and Wales, and the growing favor with which the invention has been received upon the Continent of Europe. Are we really a "go ahead" people, or do we wait with more than human patience, until inventions certainly leaning towards improvement are forced upon us by the pressure of circumstances? Surely it is time to decide the matter, and upon the side favorable to American credit, that credit which we have aforetime fairly won and ably maintained until it is again in danger.

Even in a national point of view, notwithstanding the late article by an eminent American engineer, the most ultra "native American" need have no misgivings as regards this engine. The fact of Mr. Fairlie standing as its inventor is but an individual matter. The invention is a clear recognition of the value of the American truck or bogie; it is founded upon it, and could not have existed without its previous existence. It is also in recognition of the superiority of our cheaply built roads over the stupendous money-sinking works of England; moreover it recognizes the American idea of equal and reciprocal benefits: that railroads should be paying investments to those who lay out their money and time upon them, and not paternal institutions, on which grumbling passengers should be provided with luxurious accomodation and carried where they want to go, at a very small price to themselves, and a very large loss to the owners.

If we consider the present used type of locomotive the faults which first strike are these: If the whole weight is upon its drivers, its wheel base is too long; it traverses curves roughly; and on an unballasted road can hardly be held in place. If the leading wheels are upon the trucks, one-third of its adhesion (more or less) has been lost, and this third becomes so much non-paying weight, which requires coal to be burned, men to be paid, oil, tallow, and waste to be purchased and construction money to be spent, in pushingit along.

Behind is the tender, adding nothing to the power, but weighs 20 tons (more or less) and costs so much, say a car and a quarter to haul. The balance is unequal,

being $\frac{1}{3}$ at one end, $\frac{2}{3}$ at the other ; so it gets along by galloping, rocking and plunging, and because the drivers are set stiff to the frame, by grinding the track, not quite so badly as its brother with the 8 wheels connected. Further, if we consider the condition of a train upon the track, with either of these monsters in the lead, we perceive this anomaly, that whilst each wheel of the train bears upon the track with a force of almost $2\frac{1}{2}$ tons, the drivers of the locomotive have at rest a weight of usually about 5 tons, and when plunging, a frequent kick of about 9 tons. Then is the anomaly, that the iron is bought and the maintenance expenses regulated, not by the amount of work done, but by one keen recognition of these very faults, which notwithstanding we cling so firmly to.

Now let us imagine two trucks, each with 4 or 6 wheels connected ; each a complete engine with 2 cylinders, etc., and each governed by ordinary rods, with the foot plate and the man upon it. Now imagine a long boiler with two fire-boxes together at the middle of its length ; poised upon the centre of each truck, say by a ball and socket centre pin, next a flexible pipe of any device practicable, connecting the boiler and cylinders, and you have the type of the Fairlie Engine.

Further, we should know that from the two fire-boxes, proceed towards each end the tubes, but that the water and steam space is unique. Then erect a cab upon the middle just over the fire-boxes with the foot plate half way up, or higher or lower ; place within the throttle-lever, working say in horizontal guides upon the centre of the boiler ; arrange the expansion and reversing gear, blower rods, etc.; place head lights and pilots at each end, and symmetrically between the cab and each end, steam domes, whistles, sand boxes, and smoke-stacks. Now upon the inside end of each truck, arrange a smooth bearing surface, upon which another surface bearing, attached to the boiler, may work horizontally within limits, and by means of springs smoothly.

The centre pins and upper bearing surfaces are directly connected to the "carrier frame" upon which the strain is thrown, and not upon the boiler shell. Both reversing rods are connected to the same lever, hand-wheel, or other device, so that when one is up the other is down, and thus the usual spring or counter weight is dispensed with—and both work upon the vertical centre line of the trucks, which, nearly fixed for all motions of the engine, requires no more than the usual flexibility for the rods. Finally, upon the "carrier frame" are built the "coal bunkers" and the "water tanks" so as to be most handy for use. There are no pumps generally used, the injector being certain in the nearness of the water tank to the boiler.

Having thus designed your engine to any weight and power you please, you have gained the following advantages : You carry no coal or water, nor any weight upon it which does not help the grip or adhesion of the drivers ; yet you have divided this between a greater number of wheels, so that in an engine of 20 tons (corresponding to a single bogie engine of 30 tons with tender), with 8 wheels, your pressure upon the track is only $2\frac{1}{2}$ tons per wheel, and in an engine of 30 tons (corresponding to a single bogie engine of 40 to 45 tons and its tender), 12 wheels will give you the same equilibriated train.

Again, placing your train upon the track, you will see all the wheels bearing nearly the same weight, and your rail costing in proportion to the work done, and to no arbitary standard. When it moves, owing to the balance weight, there is no plunging or oscillation comparatively, no useless tender nor $\frac{1}{3}$ extra weight of engine to haul, no grinding around stiff curves ; out of what was anomalous we have invoked harmony, and what every thing should be tending to in art, as it is in nature, Equilibrium.

There is near London an old "Cabbage Garden" in which has been laid an elliptical track the end radii of which are only 50 feet in length. Alongside of this garden are the works of the Company which is now manufacturing these engines ; 16 engines have been built for the Swedish Government of 25 and 27 tons each, and these have by authentic accounts been run around this track at the rate of 30 miles per hour; one or two for Peru have been built, and 16 for the Russian Government are in building. All these are required to be tested by running them smoothly around this same track at fair velocities.

The Swedish engines, 25 and 27 tons weight, are 4 wheel bogies, 10 in. cylinder, 18 in. stroke, 3 ft. 6 in. wheel diameter, and

will be required to haul 650 tons on a level at 20 miles per hour, gauge 4ft. 8½in.

Those for Peru, 60 tons weight, are to work on gradients of 1 in 27 per 11 miles, taking 130 tons in regular work, and able for 150 tons.

The smallest curves which have been worked in practice by the Fairlie engine, for goods and pasengers, are 110 ft. radius at 30 and 35 miles per hour.

Experiments have been lately made in Great Britain with these engines, and with the result that their hauling power was fully equal to their calculated duty, taking the weight as a basis. This of course gives not only 50 per cent. more load than could have been hauled by an ordinary single bogie engine with ⅔ weight on drivers, but utilizes the place of the tender, and replaces that recognized incumbrance by some 10 tons of paying freight.

In regard to economy, we have from T. D. Roberts, Esq., engineer of the Brecor and Merthyr Railway, a table of which the following is the summary :

Progress (Fairlie).—6,600 tons hauled. Coal used 34 tons, 6 cwt., being .54 lb. coal per ton per mile.

Cyclops (ordinary tank).—4,576 tons hauled. The coal used, 32 tons, 10 cwt., being .74 lb. coal per ton per mile.

Severn (ordinary tank).—4,576 tons hauled. Coal used 30 tons, 16 cwt., being .71 lb. coal per ton per mile.

That is, the Progress, with an increased consumption of 10 per cent. of coal, does nearly 45 per cent. more work.

And the following note is from General Malcom, managing director of the Berry Port and Gwendreath Valley Railway:

"I am happy to say the engine works well and economically. I wrote to our Superintendent the other day, desiring him (as he reported that we were slack) to use our small four-wheel engine and save the 'Mountaineer.' (The latter is the Fairlie engine.) His answer was that she worked far more economically than the small one."

Strange as some of these statements may appear, they have been fully authenticated by the English professional papers, which we must receive as official, and we must either recognize the facts, or take a strong stand against their possibility, which our knowledge of what has otherwise been done in this nineteenth century would hardly warrant.

But beyond this comes a wonderful fact. You might expect it, but never to the extent to which it occurs in practice. It is the absence of side oscillation, and the general smoothness of motion. The trucks take so easily to the track, the whole mass seems to fit itself so completely to the rail, that the motion appears in comparison to the ordinary hammer of the ordinary locomotive, like floating upon oil, or as Captain Tyler, R. E., Engineer of the Board of Trade, London, expressed it, "like sailing." The writer of this can say, that the more one is accustomed to riding upon the iron horse the more will he notice this feature. You see a bad place in the track, a quick swing, a badly-placed cast-iron frog, which experience in engine riding will tell you *should* cause a tremendous jerk. You wait nervously, you pass over it, and have in no wise felt it. And connected with this is another feature, that your train does not oscillate, but runs with a steadiness surprising to behold.

The flexible pipes do not leak as they were expected to do, and the other suspected causes for failure have turned out to be imagination.

It would, of course, be impossible to finish this paper without notice of an article written against this engine by so eminent an engineer as Mr. W. W. Evans.

Passing over the personal part of his paper with regret, we have only to regard at present, not whether Mr. Fairlie is the inventor of the engine, but whether it is a good one. If it is proved so, then only need Mr. Fairlie lay his claim ; and surely if it be that the others which Mr. Evans speaks of as originals were, as he says, failures, then this could not be the same and be a success.

Now so far as the writer has been able to acquire authentic information, the Fairlie engine has with more economy done as much per weight on drivers as any of the single bogie kind, and is therefore 50 per cent. better than they, in economy at least. Besides this, it utilizes the tender, and has therefore saved about 10 tons of paying load.

It is true that Mr. Evans has thrown aside Mr. Fairlie's average of 10 lbs. per ton car resistance in his calculations of power; which Mr. Fairlie answers by a comparison of resistance between English

and American trains, but both gentlemen might have been satisfied so far as relative resistance is concerned, by remarkably good authority on both sides of the Atlantic. For, on page 648, Rankine's "Civil Engineering," which is standard authority, we find that in curves the empirical formulæ obtained by him on English trains, and the formulæ obtained by Mr. Benjamin H. Latrobe (certainly standard authority), on American trains, were

English in lbs. per ton $1.4 \div$ radius in miles.
American " " $.578 \div$ " "

The smallness of these results (American) Rankine says, "compared with those (English), may perhaps be owing to the use of bogie carriages."

This is the beginning of an admission from England of the good qualities of the American truck. The Fairlie engine goes further, it accepts and adopts. True, the formulæ above are only for curves, and would undoubtedly be very incorrect for a perfect straight line without oscillation. But whenever the slightest swing takes place in a truck, whenever there is the slightest oscillation of the train, the comparative resistance of rigid wheels and trucks bears probably the same relative value, and this is everywhere. In this case, then, the practice of English engineers in using 10 lbs., and of Americans in using 5 lbs., leaves both parties correct, relatively at any rate, but causes a natural wonder as to why both parties do not take more kindly to the truck or bogie wherever it can be placed.

There is one thing in Mr. Evans's tables to which the attention of the engineer should be called, and that is the wonderful amount of adhesion utilized in the West Coast of South America compared with the same item in Britain, where Mr. Fairlie's experiments were made. The first country is generally described as having little rain or moisture, and we may imagine that the iron surfaces in contact are without that slight film or skin of hydrated oxide, which is forming every instant even in the United States. How must the same fact have been in the Fairlie experiments, when the track was generally greasy from condensing fog, and when the "only good day for engines" was described thus in the protocol. "The track was in fine order, being covered with frost." These are matters to be noticed, since we cannot suppose that the make of the engine had much to do with the adhesive coefficient.

The writer of this is disposed, however, to take issue with Mr. Evans only on one point. This is in leaving the results of trial to reports from Peru. It is a long way off. He thinks that the Fairlie engine has now been sufficiently tried, and with authenticated success, to warrant an experiment nearer home. We can furnish this trial ground in the United States, and, it may be supposed, the small sum of money necessary. Let an engine be chosen, say of 25 to 30 tons weight, and let her be carefully compared as regards performance with the single bogie engine; let damage to track and all other matters be carefully looked to; let the experiment be continued until the relative cost for repairs, etc., can be accurately estimated, and we can then decide between them, not as Mr. Evans calculates, of "Foot pounds of work done in lifting train alone, per hour, per ton of weight on drivers," but simply, so that we can all understand, of "Work done." We shall take the amount of *paying load*, find its cost, and then reduce it per dollar per ton.

A Canadian Ferry.—The Grand Trunk Railway Company of Canada has imported an iron ferry-boat to run in connection with its system between Fort Erie and Buffalo, and Sarnia and Port Huron. The steamer was built at Jarrow by Messrs. Palmer & Co. (Limited). She is something over 300 ft. long, 45 beam, and 14 ft. deep. She has twin screws, and will be able to carry a full train of passage or freight cars with the locomotive, if necessary. The steamer will be put together at Fort Erie, under the superintendence of Mr. T. Campbell, who has proceeded to Canada for the purpose.

The French Atlantic Cable.—The traffic now being forwarded through the French Atlantic cable averages above 7,000 words daily, being at the rate of 5 words a minute for the whole 24 hours, a speed which suffices to clear off all the messages sent within the day. On some days nearly 10,000 words have been transmitted in the 24 hours, showing that the capacity of the cable is much more than sufficient to convey the present average traffic.

FLOTATION OF VESSELS BY BUOYANT DOCKS.*

By Col. JOHN E. GOWEN.

In the year 1856, I received a communication from the Russian Minister at Washington, stating that his Government wished to open negotiations for the removal of the vessels sunk in the harbor of Sebastopol during the Crimean war. As a result of this, I proceeded to Moscow; and in an interview with his Imperial Highness, the Grand Duke Constantine, at that time Grand High Admiral of the Russian Navy, I submitted plans, which, being approved, were afterwards carried out under my personal direction. In the spring of 1857, I arrived at the scene of my labors, and, I may add, of my success. This last was founded upon the use of hollow docks or caissons of improved construction, which were sunk by being filled with water, and were, after attachment to the submerged vessels, rendered buoyant by pumping out the water, whereupon their diminished specific gravity readily lifted the vessels with them. The facility with which these docks could be sunk flush with the surface of the water contributed much to the steady progress of the work by avoiding the disasters that otherwise would have befallen the structures from the storms which in those seas sometimes sweep everything before them in their fury. Neither would I omit in this preliminary mention of the more important means employed in carrying out the undertaking, those by which the connection of the docks with the submerged vessels was secured, this connection being a matter easy enough in theory, but one which caused me the greatest trouble in practice. The present paper will be devoted to a description of the docks and their adjuncts, as well as to a brief sketch of the method in which they were used for raising sunken ships at Sebastopol, and of that by which it is proposed to use them in the flotation of heavily laden vessels over bars and similar obstructions in harbors and at the mouths of navigable rivers. I may say at this point that the principal object of this essay is to show that the experience gained in the one case furnishes presumptive evidence as nearly as possible approaching proof positive of success in the other.

With reference to the principle on which the operation of the docks depended, that of submergence by filling with water, and buoying by emptying the water to replace it by air, the same idea is embraced in the well-known "camel." This was devised by Bakker, of Amsterdam, about the year 1688, and has been employed with much advantage not only in Holland, but in Venice, on the Tiber, and in other places. This apparatus, which may even yet be used in some operations of minor magnitude, is a curious contrivance. It consists of twin hollow vessels, so arranged that they can be applied on either side of a ship's hull. They are made water-tight, and on the deck of each, windlasses are attached by which ropes passed under the vessel's keel are worked. Each half of the camel is allowed to fill with water, which sinks with the weight, and when the ropes are adjusted the water is pumped out, and the buoyancy of the hollow vessels lifts the ship out of its bed at the bottom of the stream. Of course, attempts have been made from time to time to provide substitutes for the camel. About the year 1849, an invention was submitted to the United States Government, having for its object the raising of vessels by means of air-tight cases, composed of several thicknesses of canvas and india-rubber, with a strong netting on the outside. Upon a trial which took place with a view of ascertaining the value of this invention as a means of bearing a vessel over a river's bar, it is notable that a sloop-of-war in Baltimore, having a number of cases attached (if I recollect right, 20 on either side), was only raised some 18 in. Government, however purchased the apparatus, and soon discovered that for the intended purpose (viz., the raising of submerged ships) the method was a total failure. I shall refer to an instance in which I also met with the same results, and in connection therewith detail a mode that may be used to advantage in those cases where, for any reason, it is preferred to remove a sunken vessel piecemeal.

* A paper read before the New York Society of Practical Engineering.

About the year 1843, the United States steam frigate Missouri was burned and sunk in the Bay of Gibraltar, causing an obstruction which was the subject of complaint by the British Government. Upon its representation, the United States Government undertook to remove her, and in various ineffectual attempts expended no less a sum than $100,000, the engineers employed reporting that it was impossible by human ingenuity to effect the desired end. In 1851, upon a second application from the British Government, it was resolved to make a further attempt, and I was honored with a commission to carry out the project. I found the vessel (a first class war-steamer) sunk in about 6 fathoms, and laid over broad on the bilge, having about 3 fathoms clear over all, and completely covered with sand. Government had forwarded twenty of the before-named air-bags for me to test, which I accordingly did, and succeeded most effecually in bursting up the greater portion of them without getting an aggregate lifting capacity of 9 tons, and this happened generally before they were half-inflated, though each bag or case was supposed to be equal to more than 5 tons. I at length concluded that the only effectual means of removing this vessel was by exploding gunpowder beneath her keel, which I did by the following process :—

I directed the construction of pointed cast-iron cylinders, some 7 ft. in length, 14 in. in diameter, and 1½ in. in thickness, having three turns of a screw cast on the point (similar to a screw-file), filled with with gunpowder, and closed by caps secured with screw-bolts. These cylinders were placed outside the vessel in such a manner that, on being driven through the sand some 30 ft., they would arrive beneath the vessel's keel. To effect this, I used a shaft of wrought-iron, constructed to fit over the head of the cylinder. This shaft worked on a raft on the surface of the water, was turned down in the same manner as the screw-pile now in use, so that by its means the cylinders were placed in the required position, and, the shaft being removed, were exploded by electricity. The vessel was in this manner broken up, and raised piecemeal, and the obstruction entirely removed.

With regard to the canvas and india-rubber cases just previously mentioned, I may here further state that, at the commencement of operations at Sebastopol, the Minister of Marine at St. Petersburg sent me about 20 of them, somewhat similar to those which had exploded under my hands in the Bay of Gibraltar, and with these I again experimented, but with no better fortune than on the former occasion, and I finally threw them aside as practically worthless.

Concerning my system and its results, I will at once proceed to an explanation of the appliances I used, and their method of operation. In the first place, I had intended to make use of 4 floating docks (as I prefer to call them), on a smaller scale than those shown in the diagrams ; and I may be better understood when I state that these 4 docks had an equal lifting capacity with 2 of those I am about to refer to.

They were designed to lift by chains through centre well-holes, upon which plan my first attempt was made. It was, of course, obvious to me that such a process must bring the docks together as the vessel rose from its bed, but I trusted in the use of heavy anchors to keep them apart, a power which proved to be utterly insignificant. Much to my amazement, as the vessels were lifted the docks came together so firmly that all the means I had at my commaud were insufficient to start them an inch apart, although I brought into requisition steam craft, gunboats, etc., whose united action amounted in the aggregate to 1,000 horse-power.

Here was a grave difficulty, and, in addition thereto, doubts arose as to whether I could control enough lifting-power to compass the end in view. I might raise a vessel until the broken masts and top hamper touched the caisson's bottom, but could hardly hope to bring her to the surface, and at this time I was working with the lighter vessels. To meet this trouble, therefore, I determined, while altering the docks in use to meet the demand, to construct two others having a lifting capacity equal to the four smaller ones, and for this purpose had to penetrate some hundreds of miles into the country to cut the requisite timber. Suspending all raising operations until the new docks were completed, I took the field with the six, and, if you will kindly follow me, I will explain in some detail their construction, taking one of the larger ones for illustration.

The outside shell of the docks was built of plank in timber frames, zincked on bottom and sides for a distance of 3 ft., and divided into 6 water-tight compartments, in the centre of which was the well or pump-chamber. This framework was braced with trussed or open girders in such a manner as to give the whole structure the greatest strength and rigidity consistent with maintaining the necessary buoyancy and distributing the strain, when engaged in lifting, over the whole area of the docks. The cast-iron wheels over which the lifting chains passed were also braced and supported by two iron bars, and each dock was provided with an engine of 40 horse-power to work the powerful centrifugal pump in the pump-chamber, as also the winch above, to which the falls were taken, together with the valves for the admission of water, which were worked by means of spindles reaching to the deck, and opened or shut by a key-winch. Between each compartment were sluice-valves, allowing the water to flow equally into such of the compartments as might be necessary, and a pipe led from the pump through the side of the centre compartment for the expulsion of water, while another connected the pump with the hose used, as hereafter referred to, for pumping out the vessel when raised.

In raising weights of less than 1,000 tons, I rarely needed to submerge the docks, but admitting water into the after-compartments to act as a counterpoise, I could with ease run such burdens to the surface by means of the five-part fall, hooked on the lifting-chain and taken to the steam-winch. The majority of the vessels, however, which I raised, being of far greater weight, the process I adopted for them was as follows, by which mode I had a lifting capacity of over 5,000 tons :

Presupposing that the docks or caissons were moored in proper positions directly above the sunken vessels, and the lifting-chains passed beneath the bottom, the valves and sluice-valves were opened, and water freely admitted into all compartments until the docks were submerged to within a few inches of the surface of the water. All valves were then closed, the chains hauled taut by the falls, and, water being retained as before in the after-compartments, that in the fore-compartments was expelled by pumping; the vessel was correspondingly raised, taken in tow, together with the docks, to shoal water until she grounded, when the operation was repeated until the deck came above the surface; all leakages were then roughly stopped, and the hose leading from the pipes passed into the vessel, and the pump set to work until she floated and allowed me to clean out the accumulated mud, rubbish, and ballast.

It is evident that, if at any time during the operation an uneven strain on either of the chains occurred, the dock would immediately cant, giving an opportunity of readjustment before such chain could part. With the chains lay the chief difficulty; the ordinary chain-cable of familiar form was, as I knew from former experience, of no avail when subjected to a heavy strain, invariably drawing out and crushing the stud ; and when I began operations, it was with a chain consisting of solid iron links, each 2 ft. in length, and pinned together in a manner not unlike the chain which passes round the drum of a watch. This chain was manufactured of best American iron, 2 in. thick by 4 in. in width, and connected by a 3-in. steel pin. With it I was partially successful; but, after parting it like packthread more than a hundred times, I concluded it would be imperative to procure some other chain capable of resisting the heaviest strain which I could expect to meet.

I accordingly designed a chain, probably the heaviest in use up to that time, and whose links were constructed with only a sixteenth of an inch play on either side, the sides being parallel. I was, of course, obliged to send to England for this to be made. It answered the design completely, never parting in a solitary instance, and the form, I believe, is now in use to some considerable extent, its efficiency and reliability having been amply proven.

I must now speak at some length of the difficulties which, as intimated in the opening portion of this paper, attended the proper connection of the docks with the submerged vessels intended to be raised by the buoying power of the apparatus. This, the proper slinging of the vessels, was the hardest of all the problems encountered in the work. I had secured enormous lifting power, but for a time it bid fair to be utterly useless, through the

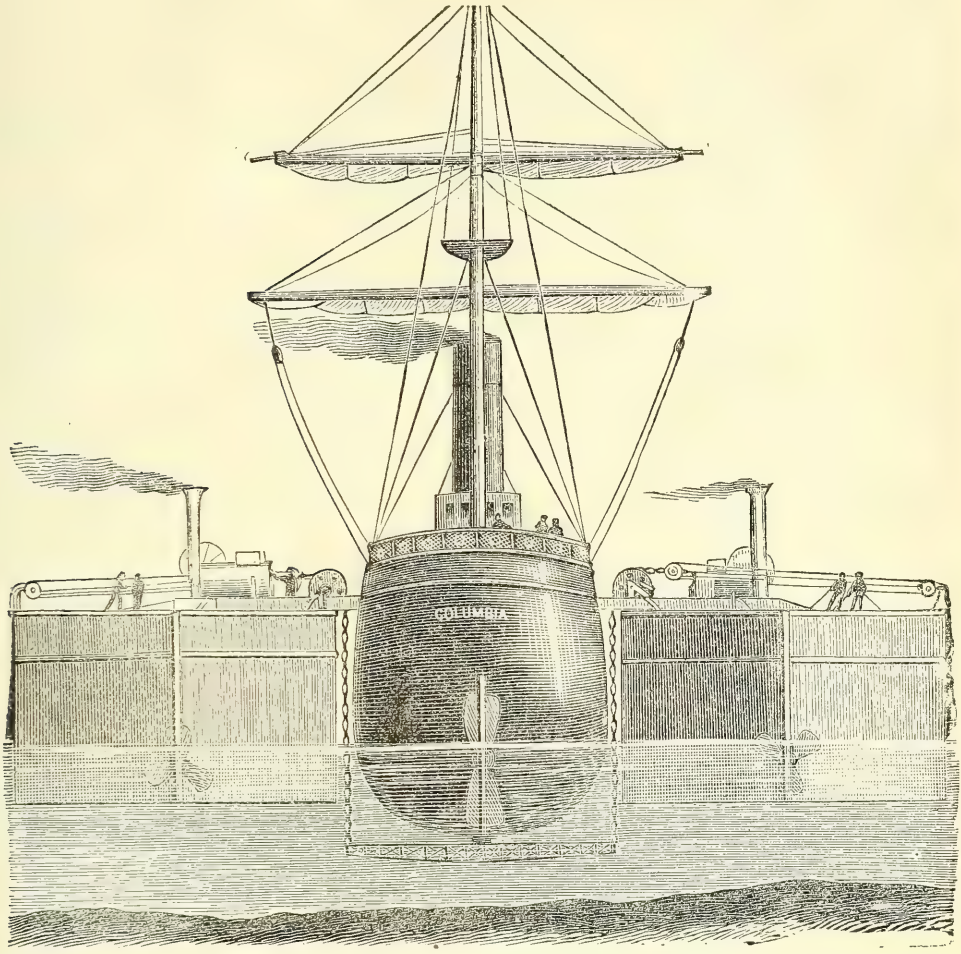
inability to attach it to the weight designed to be raised. I tried every method of slinging without success; and it is only those who have had practical experience with the subject who can form an adequate idea of the difficulty of placing ponderous chains of the character named. Upon every attempt to sling, either by sweeping or girding the vessel to be raised, the chain parted or slipped; when I led the chains through the ports, they cut up everything. I then had recourse to the following expedient upon a 60 gun frigate. With the impediments necessarily attending such work, conducted at a depth of some 60 ft. below the surface of the water, I contrived to cut four holes through either side of the vessel below the orlop deck, about 16 in. in diameter; and after crowning the same with one-inch boiler-plate, passed the lifting-chain through the aperture, hauled taut, and attempted to weigh the vessel. With irresistible force the chains cut up through everything, and thus another failure was registered.

I now became convinced that the sole method which would answer was bottom slinging; and, turning my mind in that direction, I accomplished my design by the very simple means of placing chains of the size previously described beneath the keel of every vessel with dispatch and satisfaction.

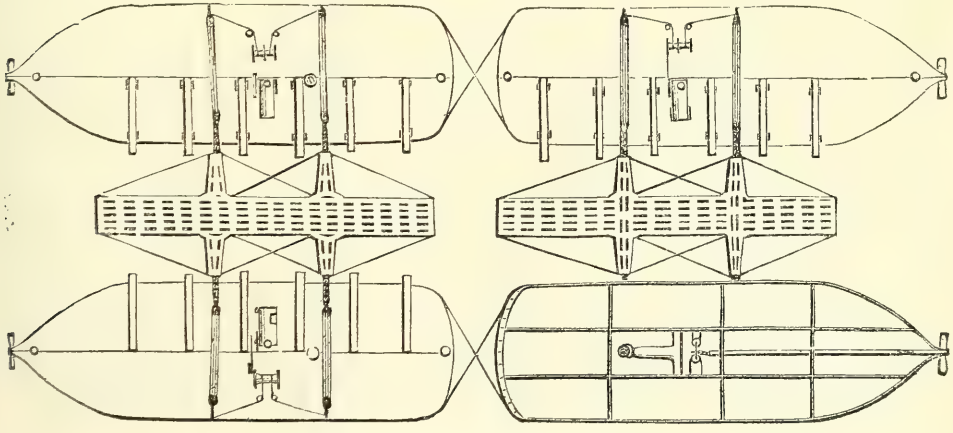
I had a flat iron scraper, about 2 ft. in width and 18 in. in depth, constructed of $\frac{1}{4}$ in. plate iron, to which a strong iron handle was riveted. To this handle was made fast a rope, carried to the capstan in a vessel moored alongside the docks, and a diver having conveyed it down and adjusted it against the side of the ship at a point where the chains were required to be placed, the scraper was drawn from above through the mud, readjusted and redrawn, until a channel had been made along the vessel's side to within a short distance of the keel. The diver then made use of a long, curved, flat-pointed iron rod, having an eye in the head through which was passed an inch rope. This he pushed under the vessel's keel, and it was drawn through from the other side by the diver occupying the corresponding channel. In this manner a way was opened for the introduction of small chains, and ultimately of the heavy lifting chains themselves, which were hauled through from above and attached to the dock. Thus what threatened to prove an insurmountable obstacle was happily overcome, and from that time on I met with no worse difficulty than occasional bad weather. One incident of the work was the fearful degree to which the wooden vessels were honeycombed by the teredo, every inch of timber not covered by mud being perforated in all directions. With the iron vessels, however, I was particularly fortunate. In the case of the war-steamer Elborross, which was docked, even the paint was in order, save where the chains had chafed, and that vessel was subsequently in commission as the yacht of her Imperial Majesty the Empress of Russia. I may here be permitted to mention that for this labor of raising and removing intact more than seventy ships-of-war in the harbor of Sevastopol, I received the public thanks of the Emperor of Russia, who remarked that I had introduced a system and performed a species of engineering which had no parallel; and I was also knighted by Russia, France, Italy, and Turkey.

I would now request your attention to a concise demonstration of the fact that my system of ship-raising can be applied with great facility and advantage to the lifting and floating of vessels of all descriptions over sand-banks and bars at the mouths of rivers and entrances to harbors and ports.

The accumulation of sand and mud in these localities may rightly be ascribed to a diversity of causes, prominent among which may be mentioned two in particular—the winds and currents. They collect and pack together any loose *debris* they may find; and just so long as these overwhelming forces are destined to act, will the process of filling up and obstructing continue, and the vital necessity exists for clearing away such deposits, in order to keep open a channel wide and deep enough to admit of the ingress and egress of freighted ships; or else, as is now the practice in many places, the freight will have to be conveyed beyond the bar by means of lighters to meet the ship whose draught excludes it from the harbor within—both of which resources are far more elaborate and uncertain than the very simple, safe, and economical method of buoying up vessels, the efficacy and facility of which I have made known to you this evening.



COL. GOWEN'S SYSTEM OF BUOYING VESSELS.



Dredging has hitherto been resorted to, and resolutely carried forward, and is to-day practised in various parts of the world to a very considerable extent, but in most cases without permanent utility. I might cite the instance of the mouth of the Danube, where, perhaps, the most extensive system of dredging known has been pushed on with praiseworthy vigor from time to time for the past quarter of a century. But I need not look so far away, for dredging, as a means of clearing a channel, has been abandoned as utterly hopeless and worthless, and a waste of time and labor, at the passes of the Mississippi; and numerous instances might be named of failure in the prosecution of this useless work along our seaboard. It may afford a momentary relief in some cases, and a slight increase of water might be obtained; but just as soon as the dredging is discontinued, the sand and *debris* are again deposited.

Many millions of dollars have been literally sunk in the sea in futile attempts to remove, by dredging, the bars and like obstructions from commercial ports. At the approach to the Bay of New York, a port of entry unsurpassed in the world, exists an obstruction which effectually prevents the passage of vessels drawing more than 22 or 23 ft. at average high tides, and which defies the best skill of engineers to remove or keep in check. The steamer Italy very recently was delayed outside of the Narrows for several hours, until she could run in on top of the tide, she being of tolerably heavy draught; and the same company to which she belongs are now engaged in constructing still another fine vessel to draw a couple of feet more than the Italy, and which will be effectually barred by sand and silt. We all know that New York harbor is not an isolated example. Philadelphia, Charleston, Savannah, Mobile, New Orleans, and Galveston are each of them fine ports, but similarly closed to commerce, and to a far greater extent. Philadelphia, as you know, stands on a peninsula between the Delaware and Schuylkill rivers. Its harbor is at the head of the ship navigation of Delaware Bay, a vast arm of the sea. But with all their natural advantages, it is only at the full tide that sea-going ships are able to pass the harbor and river obstructions; and in most cases they are obliged to await repeated tides, in order to proceed up as far as the city. At the mouth of the Mississippi the difficulties are of the most formidable character, and such as to preclude the passage of vessels of ordinary tonnage. The port of New Orleans is bound up by a bar with but 17 ft. water, despite all the efforts which have been made to dredge out and deepen the channel.

I need refer at no greater length to the stoppages which lie all along our coast and block up our ports. You know of them as well as I do, and of the struggle to overcome them. We fully realize the importance of the evil, and the simple question comes up:—"What must be done?" I think I can tell you. What is required is a method by which vessels of the largest class can enter port with their freight, unload, take in cargo, and again depart free from all danger of detention. And this, gentlemen, I do not hesitate to assert upon my professional judgment, *can be done.*

In a few words, I will describe to you a positive remedy—a system by which vessels of the heaviest tonnage may be safely and quickly *borne over* a bar, and that too at a comparatively moderate outlay. Every vessel which I raised at Sebastopol I triumphantly carried a distance of more than 5 *miles while suspended to the floating docks;* and this without straining a single timber, as they hung as securely in the supports, and were borne along as gently, as if resting on the buoyant bosom of their native element. It is by the very same principle of operations that I propose to do away with the necessity of dredging, and to make our harbors and rivers accessible to vessels of the deepest draught.

I will now describe the way in which I propose to float vessels into port, the machinery I shall make use of, and its mode of application. The machine which I propose to use will consist of 4 floating docks, of wood or iron; each dock about 160 ft. long, and 50 ft. in breadth. They are pointed at the bow and blunt at the stern, like a row-boat, and have a depth of 25 ft., each dock being divided into 9 compartments, into which the water is admitted by means of valves in the bottom, and the sides of the compartments are also provided with other valves, whereby the water can be allowed to flow from one compartment to another. When it is

required to submerge the dock, the valves in the bottom are opened and the compartments fill with water, which is expelled when required, by the action of a centrifugal pump connected wilh each compartment by sluice-valves. Each dock is provided with a steam engine of 50 horse-power, which serves the purpose of propulsion and also works the pump and chains. All the bottom valves are opened and closed by suitable rods or levers extending to the surface of the deck, and by means of sluice-valves the communication between each or all of the compartments and the pump-chamber is opened or closed at pleasure, and the water can thereby be confined to the after-compartments, to balance the weight of the vessel to be lifted, or allowed to flow equally all through the dock. The pump-chamber or central compartment must be made water-tight, but the other compartments need not be so constructed.

Now picture to yourselves two of the floating docks standing stern to stern and held together by strong cables, and parallel with them the other two docks, similarly connected at the stern, each pair of docks being far enough apart to admit of the action of the cradles or supports which are to hold the vessels to be buoyed up. The cradles are built of iron, and are simply flat floors 120 ft. long and 15 ft. broad. The pulleys over which the main or lifting-chains pass are supported so as to turn freely in strong iron brackets, which are firmly secured to the deck of the dock, and are strengthened by diagonal tie-rods, whose lower ends are secured in shoes to the bottom of the girders. The lifting chains are passed through holes in the brackets, and are held fast by clamps bolted to one of the links behind the brackets. These chains are attached to strong running blocks or sheaves, which are connected with the ropes or chains; the latter are passed over suitable guide-pulleys and through the fixed blocks to the barrel of the winding machinery arranged in the centre of the dock. Two cradles are used in the process of lifting, which lie in a horizontal plane, and to end, one being slung from each parallel pair of docks, and both being employed to sustain the weight of the vessel.

I know whereof I speak when I assert that I could lift and bear the Great Eastern, the largest steamer afloat, over the bar at Sandy Hook, and carry her out again, without straining a single plate or screw during the process; and no better test than that can be imagined or will be likely to occur. One of the vessels which I raised in Sebastopol harbor weighed upwards of 5,000 tons, and in addition was filled with mud and debris; and to do this I was obliged to resort to no greater precautions than I had taken with the others.

The objection may be raised, that if dredging and channelling were to be entirely suspended, accumulations might continue to increase until the inlet to harbors would be altogether stopped up. But a moment's reflection will show that this could never be, on account of the constant working of natural laws. The river must find an outlet large enough to permit it to empty itself into the sea. Spring freshets with augmented force would contribute to sweep away a portion of the winter's debris, and the ebb and flow of the tides must exert a continuous influence unfavorable to the complete closing up of a channel. Indeed, experience proves that sand-bars remain of nearly the same proportions during long consecutive periods; and if by any remarkable combination of circumstances the mouth of a river should become entirely blocked up, the stream would soon furrow for itself a new and sufficient passage with increased and irresistible impulse. During the late exhaustive war in this country, all dredging operations at the mouth of the Mississippi were suspended *in toto*, and for the period of four or five years the income in the deposit at the bars was quite imperceptible or infinitesimal. On the contrary, if the natural accretion is disturbed, but a correspondingly short interval elapses before the mighty influences of tide and wind and element combine to bring back the lost debris and restore it to its former place. Here let me speak of the immense traffic in breadstuffs which would undoubtedly be carried on were our harbors once thrown open to large draught vessels—a traffic which might make this country the source of grain supply for the countries of Europe. It costs the price of two bushels of corn in freight to bring one bushel of corn from the West by rail to the city of New York; that is, two bushels in every three are consumed

in transportation; whereas, if floated down the Mississippi, and thence across the ocean, to which there is no natural impediment except the shoal water at the mouths of that vast estuary, breadstuffs could be sold in France and England as cheaply as, and of a better quality than, those imported into those countries from other sources. The chief supply of breadstuffs for the European market is now derived from the broad fields of Russia. $100,000,000 worth of grain from that empire is annually consumed in Great Britain and France alone. What a magnificent market is that for the employment of American enterprise and industry! With the port of New Orleans accessible to first-class vessels, say of 5,000 or 6,000 tons burden, the native products of our Western States would be shipped abroad at a figure defying the competition of the world, and an impulse given to the agricultural interests of this country which would make us the grain-growers, *par excellence*, of all Christendom.

I have spoken more particularly of New Orleans in connection with the exportation of Western breadstuffs to Europe, for the sole reason that the great natural artery of our continent, the Mississippi, passes out at that port of shipment, and thus offers the easiest and cheapest route to the Atlantic, But the discouraging fact stares us in the face that ships of sufficient burden to bear our breadstuffs to a ready market, at low prices, cannot get over the sand-bars which block up the port. It costs less to employ vessels measuring 5,000 or 6,000 tons in a carrying trade across the ocean than it does to make shipments in vessels of 600 or 700 tons. Any shipping merchant will answer for the accuracy of this statement. And again, the distance between New Orleans and Great Britain is no greater than between Southern Russia and Great Britain.

During a conversation I recently had with the able and far-sighted President of the Central Illinois Railroad, said he: "If the harbor at New Orleans can be opened up, I see no reason why the grand granary of the West should not empty itself, in an unbroken flow, into the lap of Europe. We have the corn, we have the great canal, but we cannot freight the ships at New Orleans, but have to send by rail to open ports, where corn can be shipped at the wharf."

Hitherto, gentlemen, our crops of corn and wheat have met with little sale abroad; and it is only in times of destructive and engrossing wars in Europe, of drought or famine, that we have succeeded in sending our products there at remunerative rates. We have not been able to compete with far-off Russia in this trade. But sweep away the bars which hedge in our bays and our harbors, and the great grain-fields of the Western States will be as accessible to Great Britain and France and Germany as now are those which, rich with harvests, lie within the boundaries of the Muscovite dominion.

RETAINING WALLS.

The following graphic method for determining the pressure of earth against a retaining wall, we take from "Engineering:"

Referring to Fig. 1, let us determine, first, the pressure exerted by the wedge, A, B, C, the angle, B, A, E, being greater than Φ, the limiting angle of resistance of the wedge against A, B, which is also identical with the natural slope of the earth. The friction against the back of the wall is neglected. We have now 3 forces to deal with — namely, the weight of the triangle, A, B, C, acting vertically through its centre of gravity, and therefore passing through the point, c, where A, $c = \frac{1}{3}$ A, B; next, the resistance of the plane, A, B, the direction of which is inclined at an angle, Φ, to the normal to A, B; and, lastly, the thrust against the back of the wall acting horizontally through c, and cutting A, C in a point, g, where A $g =^1$ A, C.

Now, since the weight of the wedge, A B C, is proportional to C B, the height of the wall remaining constant, and the slope varying, if we set off $c\ b =$ C B, and complete the triangle of forces, $a\ b$ will represent the thrust against the back of the wall.

Let us now observe the effect produced by altering the slope, A B, to A D. the weight of A C D. The angle, *e d f*, is now greater than the angle, *a c b*, by the same amount that we have increased the slope of A B to A D; that is to say, the angle, *e d f* = *a c b* + angle D A B.

Also, the length of *b c* has decreased to *f d* in the ratio of C B to C D.

Supposing now we divide up the angle C A F into any number of equal angles by the radial lines A_1 A_2 A_3, etc. (see Fig. 2), and imagine the slope of A B to be altered to each of these positions successively, we shall then for each alteration have a new triangle of forces; for instance, in moving from the position A_1 to A_2 the angle, *b* A *p*, of the triangle of forces will increase to c A *q* in the same ratio that C_1 decreases to C_2.

We are thus enabled to make a diagram illustrating the successive changes by a curve, *e d c b*, A *b*, A *c*, A *d*, etc., being respectively equal to C_1 C_2 C_3, etc. The lines *b p*, *c q*, *d r*, *e s*, and *c* drawn at right angles to A *b*, A *c*, A *d*, etc., will now represent the thrusts against the back of the wall at the different slopes, and it will be observed on examining the diagram that the position which gives the greatest magnitude to the line representing the thrust is the slope, A_4, which bisects the angle C A F.

Construct the triangle of forces, *d e f*, as before, making *d f* = C D, to represent that the slope of the plane varies, and the side A *b* will decrease to A *c* in the

Fig. 1.

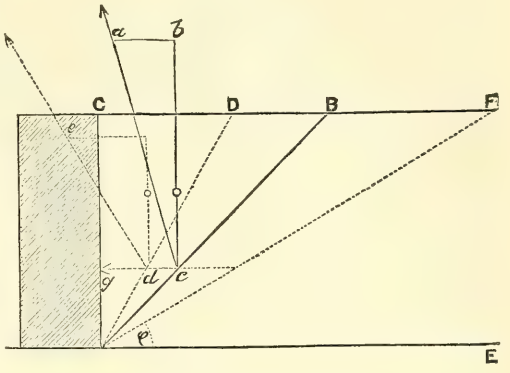
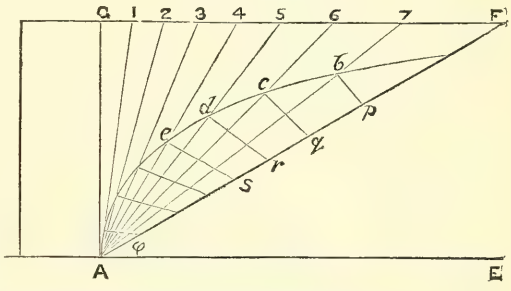


Fig. 2.



FLOATING MARINE TORPEDOES.*

By M. L. CALLENDER, M. E.

Considered from a practical stand-point, torpedoes, although proposed and to some extent used many years ago, seem to have first been made really serviceable and effective by the Confederates against the navy of the United States during the recent civil war. These torpedoes were of various ingenious forms and devices, generally the "submerged" or "anchored torpedo," and the "floating torpedo" or "infernal machine" to explode by percussion of the contact of the enemy's vessel or by clock-work. The floating torpedo depended upon the tide to float it against the enemy's vessel. The ingenuity of our navy was put to the test to devise means to neutralize and destroy these formidable machines, which was done by fishing them up or "grappling and dragging for them," and by using counter-explosives or torpedoes. There is no question that the exigencies of those days conduced more to the advancement of this branch of warlike art than anything that had occurred before; and attracted the earnest attention of other nations to the great importance of this species of warfare. Prussia has succeeded best in the general results of her efforts, looking to defence against the type of vessels known as the Monitor, not, as England has done, by piling upon iron-clads layer upon layer of iron plating, until, like the ill-fated Captain, they are

* Paper read before the New York Society of Practical Engineering, Jan. 18, 1871.

liable to capsize at any moment, but by following up the experiments and perfecting the torpedo system, which was initiated here during our late rebellion. The plan, however, of placing stationary explosives in the bottoms of harbors and rivers is extremely limited in its efficacy, because the enemy may avoid or neutralize their effects to a considerable extent, as was demonstrated in our experience with the Confederate torpedoes. These facts are evidently appreciated in Europe, for we have reports of different devices invented with a view to overcome the deficiences just mentioned.

Capt. Luppis, a retired officer of the Austrian navy, recently conceived a "floating and travelling torpedo," the fore part of which contained an explosive material, the after portion being occupied with the propelling power, which was steam. Mr. Robert Whitehead, an English engineer, saw the impracticability of this arrangement, and designed an improvement, as he believed. This torpedo is fish-shaped, "the body forms the engine room and storehouse for the propelling power, which is compressed air, and which works an internal engine, by which an external four-bladed screw is actuated." It is to be discharged "through a tube attached to the torpedo ship," into and beneath the sea for action, and is denominated a "submarine self-propelling torpedo." It will be seen that the apparatus thus described is somewhat similar in the principle of its management and operation to that invented in 1864 by Mr. Robert Weir, of New York city, and recently described before this society, but which is much less complicated and expensive, and of greater practical utility than the foreign invention just herein alluded to. Mr. Whitehead's torpedo was tested, and found to attain a speed of about four miles per hour. The test was made in Sheerness harbor, England. The torpedo ship Oberon manipulated the torpedo, and by "backing" and finally coming to a "stand," succeeded in discharging the torpedo at and striking the broadside of the hulk Aigle, which had been moored in shallow water, at a distance of "about 120 yards." The exploding charge was 67 lbs. of gun cotton, and was, as might be supposed, quite effective upon the hulk. We understand that £56,000 was bid by the Austrian Government for the sole right to its use.

It is noteworthy that the application of compressed air and steam for propelling a torpedo was proposed and patented by the writer of this paper as early as 1862. But the application and use of the much simpler and cheaper method of propulsion, the reactive force of gases generated from a burning composition, or, in other words, by the application of the rocket principle, was settled upon as promising the greatest utility.

With these preliminary remarks, we pass to the more immediate consideration of our subject. During the early part of the late civil war, before the advent of the Monitor, and when the remarkable activity of the memorable Confederate iron-clad navy of "railroad iron" caused serious apprehensions for the safety of the seaboard cities of the North, the writer first conceived what he denominated the "water-rocket and torpedo," and submitted plans of the same to the Naval Board at Washington, who reported favorably for having it tested at the navy yard.

This invention consisted mainly of a cigar-shaped vessel of plate iron, intended to be properly ballasted to float on the water, the front portion to contain an explosive charge, and the rear to be provided with a chamber containing rocket-powder. A heavy bar of iron passed through the axis of this vessel or torpedo, and projected somewhat beyond the front, this part being of hardened steel; the object being to drive the massive bar through the side of a vessel by the propelling force of the rocket, and to explode the torpedo as well. The advent of the Monitor at about this time, with its low deck and heavily plated "overhang," which projected far beyond the hull, presented an obstacle which required a new arrangement of the water-rocket, in order to throw the explosive charge, or torpedo proper, under the bottom of the vessel, and explode it there, at the weakest and most sensitive part, with certainty and effect. This plan was soon perfected, after a series of experiments in Gowanus Bay, South Brooklyn, and finally it was deemed best to secure the invention by patent, which was done on Aug. 18, 1863, antedated Oct. 16, 1862.

The principal features embraced in this patent, and deemed to be new, were a self-propelling floating torpedo-carrier or vessel, moved by the gases generated in the principle of the rocket; the torpedo-carrier or vessel to have a sub-torpedo chamber or tube with its outlet underneath, and at a proper angle or inclination, so that the torpedo would be projected out of the tube by its momentum when the rocket or carrier struck a vessel, or by a small explosive charge in its rear; the sub-torpedo to be connected by a "guy" to the front part of the carrier or rocket, so as to be thrown with certainty up under the bottom of the vessel, and striking and exploding the percussion or primer communicating with the magazine; the rocket or carrier to be guided in its course, when necessary, to long distances by means of a rudder operated by tiller-ropes or wires extending aft to a safe distance to the operator, who occupies a very light over-decked small boat, which is drawn by the water-rocket itself until guided to its destination, when the operator rows back to his vessel or to shore, as the case may be.

The full force and scope of this invention is best expressed in the words of the specifications, hereto appended, of the patent itself, which will be readily

Fig 1

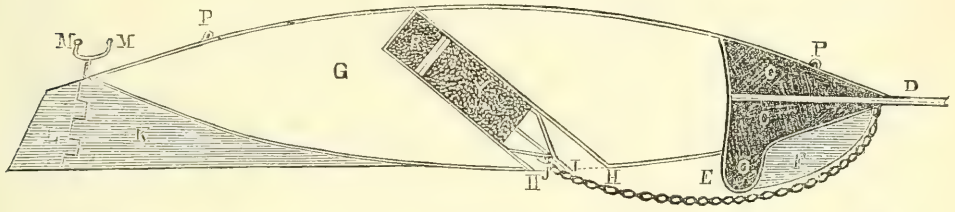
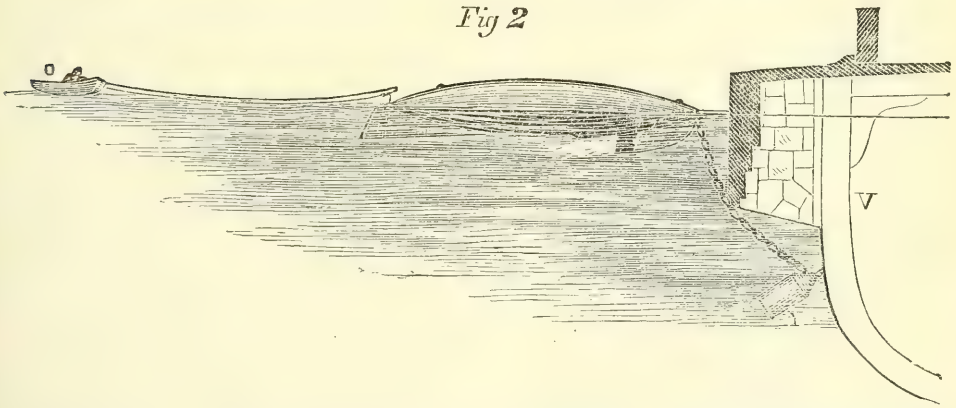


Fig 2



understood by reference to the illustrations presented in connection therewith. The patent is dated Oct. 16, 1862, and its descriptive portion reads as follows:

* * "The nature of my invention consists in propelling a proper vessel on or beneath the water by means of gases formed by the combustion of compounds that form large volumes of gases, or by compressed air, and projecting and exploding a torpedo or magazine under a gunboat or other vessel or object, or against the same. * * I construct a vessel of tin, iron, or other material, in a cylindrical form, and tapering to a point at each end, and intended to float on or under the water as the case may require. The interior of this cylinder or rocket, Fig. 1, has a partition at A, forming a chamber in its front part, through which passes and is secured a heavy bar of steel or iron, B, projecting beyond the vessel, and ending in the form of a cylindrical concave headed punch—the cutting edge being the outer circumference of the edge of the bar, with the centre hollowed out or concave at Q. The chamber, C, C, is intended to contain rocket or meal powder or its equivalent,

or compressed air, and has a hollow projection at D, with an opening or vent at E. This projection has a cut-water and brace combined at F.

"A small fixed cylinder, G, is inserted at H, H, in the larger or main projectile at the bottom, and inclines and opens only at the bottom, at an angle toward the front of the main cylinder. This is to contain a small charge of powder at R, and is also supplied with another smaller cylinder or magazine, Y, pointed and armed with a penetrating bar at its lower extremity, I, and is secured by stout staples and a chain, J, J, to the front part of main cylinder or water-rocket. At K is a false keel, a rudder, L, and rudder-posts and arms, M, M, P, P, are staple-rings by which the cylinder can be hoisted up and suspended from the davits of a gun-boat or vessel.

"In Fig. 2 is shown a small boat with a windlass or tiller at O, intended to be attached to the water-rocket by, and to operate the rope or ropes of, the rudder, L, to guide it in its direction.

"The small boat, N, may be replaced by a dummy, tow-clog, or drag, attached to the rudder, L, by a single line, to act as a self-guide by a device to be described hereafter, or it may be guided from a gunboat or vessel.

"The rocket, Fig. 2, is represented in the act of striking the side of the vessel, V, V, while the magazine, Y, is projected under and against the bottom, where it explodes. The dotted lines show the direction it moves through the water.

"This rocket, Fig. 1, is intended to move on or beneath the water by the force of gases evolved in it by combustion of semi-explosive compounds, or by compressed air, either directly as a reactionary force or by the aid of mechanical appliance, as a screw or paddle-wheel, when moved by explosive gases or compressed air, etc. The rocket is to be suspended by davits on a gunboat or vessel, or secured in some convenient and ready manner, so that the fusee, E, can be ignited, and the rocket lowered and cast loose readily, obtaining its direction and an initial velocity by the momentum given it by the motion of the gunboat or vessel, which is increased by the gases escaping from the chamber, C C, until it strikes the object to be destroyed. When used thus, the rudder L, guide ropes, etc., will not be used, as the gunboat will be sufficiently near to render it unnecessary.

"But otherwise it may be used with and directed by the aid of a small boat, or kept in its original direction by a tow clog or drag without the aid of a small boat, tiller, and man, or it may be started directly from the shore.

"The magazine may be a part of the rocket, or be a separate cylinder, as at Y, which is to be projected against and under the vessel to be destroyed, or other object, by its own momentum, when the rocket strikes, or by a small charge of powder, as at X, to explode when the rocket strikes; the chain, J J, operating to give it a direction to bring it more certainly against the bottom of the object, where it is exploded by either a percussion or time fusee.

"The hollow or concave punch is intended to cut in and penetrate when striking at an angle, without glancing off, and this same principle will apply to any kind of projectile.

Experiments made by the writer demonstrated that submerged self-propelling torpedoes of the Luppis & Whitehead type may be made effective; but their efficiency is quite limited, for reasons which the practical mind will readily conceive. The recent experiments at Sheerness, England, with Mr. Whitehead's invention, show conclusively the inutility of discharging a torpedo under water at a moving object any distance in deep water, when, in order to strike the hulk Aigle's broadside at a distance of only about three or four hundred feet, it was necessary to have it rest on or near the bottom of a shallow bay, while the torpedo ship Oberon had to "back astern" and finally come to a "stand" before discharging the torpedo.

If we take into account the exigencies of warfare, of tides, currents, winds, and waves, of vessels moving and manœuvering by wind and steam, it will be admitted to require a weapon of *long range*, that can be guided with precision towards an object, that will drive the explosive under and against the bottom of an enemy's vessel with certainty and deadly effect, that can be effectually employed at sea as an arm of marine warfare, and also operated from shore for coast and harbor defence. The element of *cost* of the torpedo must be also taken into account, and the simplicity of its construction and operation.

RAILWAY GAUGES AND ROLLING STOCK.

From "Engineering."

Upon a first consideration it appears somewhat strange that, after so many years of such varied experience in railway construction, the gauge question should yet remain unsettled, and that so many erroneous ideas should exist upon the subject—so many false notions as to relative cost, as to relative capacity, and as to relative speed. Yet it is so. "The battle of the gauges" almost twenty-five years since was fought upon a very broad platform. It was then the question between Brunel's magnificent gauge and the more moderate gauge of less monumental engineers. Yet, even then, none contemplated anything less than the narrower width; and, later on, when Mr. Simms recommended the gauge that was afterwards adopted in India, he was influenced by a wish to make a compromise between the doctrines of the two schools. Similar to the arguments advanced now were the arguments advanced then, and much as the want of absolute knowledge shown then is the want of absolute knowledge shown now. There are but very few who have had practicable experience of the cost, the facilities for working, and the capacities of the 3 ft. 6 in. gauge, and none who have had any experience worth recording about a 2 ft. 9 in. gauge. Yet it is from these two widths, or something between these two widths, that the Indian Government has to make its selection in deciding upon the large secondary system of railways that have to be commenced, and that immediately, if India is to have a fair chance given to her for development during the next twenty years.

It is freely admitted now that the costly policy advocated by Mr. Simms, and indorsed by the East India Company, is a failure. It is freely admitted that India cannot afford to extend her railway system upon the existing plans, except so far as feebly and slowly throwing out short branches, or extending its trunk lines here and there. It is freely admitted that a great railway system in India is impossible, if some total change is not effected which shall, with an outlay within her means, give her sufficient accommodation, neither more nor less than she requires. It is just this "neither more nor less" that is the troubled question. It involves many problems. Political necessities and commercial necessities, the probabilities of future development, the chances of sudden calls upon it for the putting forth of its full capacity, the probabilities of comparative stagnation of business during certain seasons. But two gauges are admissible — the existing one, all too wide, with its narrow rolling stock, still too large for the demands upon it, and the gauge yet to be decided on, one that shall be able to accommodate the maximum traffic with the minimum outlay, at once the most efficient and the most economical.

In deciding this question of the narrow gauge as between 2 ft. 9 in. and 3 ft. 6 in., there are three great questions to be considered: first, cost; second, capacity; third, speed. The first is connected almost entirely with the construction of the road, the second and third have to do with the rolling stock principally.

So as regards cost. The advocates of the wide and those of the narrow gauges propounded until recently, and some do even now—the one, that the reduction in the cost of a narrow-gauge line was only as much as was represented by the reduction of width between the rails; the other, that the difference in cost varied in direct proportion to the gauge. Collateral to these were the respective convictions; on the one hand, that in a narrow-gauge line all other elements of expense must remain unaltered; on the other hand, that the elements of expense decreased just as the rails approached each other. We believe that these convictions are gradually fading out, and that it is becoming admitted that it is not the *gauge* that rules the cost, but the numerous items that enter into the whole schedule of a cheap railway bill, of which the gauge is but one. How far, then, does the cost of a cheap narrow-gauge railway compare with that of a broader gauge? The first standards for comparison that present themselves are the ordinary 4 ft. $8\frac{1}{2}$ in. and the 3 ft. 6 in. gauges. But to establish a comparison, it is necessary to exclude so many condi-

tions, and to include so many others, that it is difficult to arrive at a conclusion. The experience of few of our engineers helps us here; but we are fortunate in possessing the result of the experience of Mr. Carl Pihl, the Government Norwegian railway engineer, who must and will always be remembered and recognized as one of the leaders of railway reform. Those of our readers who care to refer to the numerous communications from Mr. Pihl that have appeared from time to time in these columns, and to the equally numerous articles in which we have availed ourselves of the experience of that gentleman, will agree with us in what we have said, and will be satisfied to take his results without hesitation.

In Norway, then, where the 4 ft. 8½ in. gauge was established first as the standard of the country, but where the 3 ft. 6 in. is the recognized gauge, we shall find all we require to establish the comparison of cost between the two widths, and which we have long ago published. From a careful investigation, Mr. Pihl shows that the saving in the narrower over the broader is about ⅔ds of the outlay—a result borne out not only by the cost per mile of lines now built, but by carefully prepared estimates for lines of the two standards running over the same ground. How, then, will the question stand between 3 ft. 6 in. and still narrower widths? We subjoin a careful estimate of cost per mile for lines of varying gauge.

No. I.—*Table of Comparative Cost per Mile of Railways of Varying Gauge.*

Width of Gauge.	Formation width.	Excavation.	Drainage works.	Bridges.	Ballast.	Sleepers.	Permanent Way, 45 lb. rail.	Fencing.	Stations.	Contingencies, 20 per cent.	Total.
4 ft. 8½ in.	15 ft. 0 in.	£521.9	£73.00	£105	£102 1	£217.65	£626 8	£150	£135	£526 29	£3157.74
3 6	13 6	581.9	70.00	383	314.0	171.00	626 8	150	135	486 5	2918 2
3 0	13 0	5687.	69.00	375	301.3	155.37	626.8	150	135	476.22	2857.39
2 9	12 6	555 35	68.00	367.5	294 9	147.64	626.8	150	135	469.03	2814 24
2 6	12 0	512.0	67.00	360	288.5	139 92	626 8	150	135	461 810	2770.06

No. II.—*Table of Differences in Cost on Railways of Varying Gauge.*

Gauge.	Difference in width of formation.	Excavation.	Drainage.	Bridges.	Ballast.	Sleepers.	Permanent Way, 45 lb. rail	Fencing.	Stations Workshops, &c.	Contingencies, 20 per cent.	Total.
4ft. 8½ in. }	1 ft. 6 in.	£40.0	£3.0	£22	£88.1	£46.65	....	....	....	£39.79	£239.54
3 6 }	0 6	13.2	1.0	8	12.7	15.63	....	....	....	10.28	60.81
3 0 }	0 6	13.35	1.0	7.5	6.4	7.73	....	....	....	7.79	43.15
2 9 }	0 6	13.35	1.0	7.5	6.4	7.72	....	....	....	7.19	43.15
2 6 }											

The above tables are based upon careful and detailed estimates of an existing line and may be taken to represent a type of a first-class single track railway. It will be seen that in three of the large items, namely, rails, fencing, and stations, the amounts are constant, whilst the other items of cost are reduced in a proportion much more moderate than would be imagined, the total difference between the 3 ft. 6 in. gauge and that of 2 ft. 9 in. being only £104 per mile.

Coming more nearly to the case in point, to the consideration of cost between a gauge of 2 ft. 9 in. and one of 3 ft. 6 in., for the Indian railway system, we have to learn what economy will be effected between the two. To do this properly, we must have recourse to an actual example, to a proposed line in India that has been carefully located, graded, and estimated, having the same weight of permanent way in each case, namely, 42 lbs. to the yard. And, first, we will take the cost of the gauge of 5 ft. 6 in. per mile, the assumed formation width being 14 ft.

Earthworks	£295.2
Permanent way, 42 lbs. per yard, to include fastenings, sleepers, ballast, laying, etc	2,248.0
Slidings 10 per cent.	224.0
Bridges	812.5
Telegraphs, etc.	157.0
Stations and workshops	625.0
Contingencies and Charges	1,034.0
	£5,395.7

We now come to the 3 ft. 6 in. gauge :

Earthworks, formation, width, 10 ft. 6 in.	£258
Permanent way, sleepers, ballast, laying, etc	1,790
10 per cent. for sidings	179
Bridges	729
Telegraphs, etc.	157
Stations and workshops	558
Contingencies and charges	872
	$4,543

The last summarized estimate will be for the 2 ft. 9 in. gauge :

Earthwork for 9 ft. 6 in. formation	£348
Permanent way, sleepers, ballast, laying, etc	1,690
Sidings 10 per cent.	169
Bridges	729
Telegraph, etc.	157
Stations and workshops	558
Contingencies and charges	845
	£4,396

The respective savings in these three estimates are £824 and £147 per mile.

But it must not be forgotten that if the percentage of sidings allowed in the 3 ft. 6 in. estimate is sufficient, 10 per cent. is too large a proportion to add to the account of the 5 ft. 6 in gauge, and not enough for that of 2 ft. 9 in. The length of siding room required for the narrower gauge would vary in an inverse ratio to the cross section of the loads carried by the rolling stock, a matter upon which we have dwelt in another column. It is, therefore, being within the mark to add 12½ per cent. instead of 10 per cent. to the siding accommodation of the 5 ft. 9 in. estimate. This would give an additional sum of £42 per mile to be added, reducing the difference of cost to £105 per mile. The outlay for the railway of 2 ft. 9 in. gauge would thus be 97.7 per cent. of that with the 3 ft. 6 in. gauge, making a difference of 2.3 per cent., showing a saving sufficient to construct 165 miles upon the lighter system, out of the 7,000 miles proposed for the secondary *réseau* of India.

We should not omit to state that in framing the foregoing estimates from the more detailed figures of the reports, we have allowed for the same weight of rails in each case. Messrs. Strachey and Dickens, however, propose to employ a 36-lb. rail, which, however suitable it may be for the traffic it is designed for, is nevertheless inadmissible in forming a comparison of cost. The consideration of weight of rail in relation to gauge, we shall discuss on another occasion.

It will be noticed that the differences of cost per mile between the two estimates framed for the Indian railways, and those tabulated above for a line in this country, are identical. This exact agreement is, however, merely a coincidence, for the different conditions involved in the construction of various lines, would of necessity produce discrepancies in the comparison of the proportion of cost to gauge, ranging between the conditions of a light surface line, where the difference would be least, and railways running through such a country as that of Norway, where Mr. Pihl has found the cost of the 3 ft. 6 in. lines to be only two thirds of those of 4 ft. 8½ in. wide.

We think little more need be added to dispose of the question of economy sought to be effected in the adoption of the extremely narrow railways advocated by Colonels Strachey and Dickens. It may be urged that the partial estimates given are insufficient to allow a practical and valuable opinion to be formed. But as these estimates are framed for a proposed railway 480 miles in length, the basis is sufficiently extended to argue fairly upon, and as the figures show that by adopting a width of 2 ft. 9 in. instead of 3 ft. 6 in., a saving sufficient to construct only 11 miles more of line of equal character could be effected, the advocates of this system must abandon the argument of economy and occupy other ground. It is only just to the authors of the report advocating a width of 2 ft. 9 in., that they do not urge emphatically the argument of economy; indeed, they say that however small the difference of cost may be between a railway of a gauge that is enough and a railway on any broader gauge, it is the duty of the Government to select the one, and avoid the other, in making their final selection. But it is exactly in that question of what is enough that we consider Messrs. Dickens and Strachey are at fault. The carrying capacity of a railway, and the

speed at which trains may be taken upon it, are the measures of its usefulness, and in selecting a gauge, the maximum amount of work to be thrown upon it, must be considered, and not that which it would have to perform under ordinary conditions. The importance of this consideration cannot be too prominently kept in view, and any error of selection committed now, would be irreparable, or remedied at best with an enormous outlay. The time may arrive, and in these days no one can forecast events, even in the immediate future, when the safety of India as a British possession may depend upon her railway system. How shortsighted, then, would be that policy which should advocate the adoption of a gauge "wide enough" for her requirements, that is, wide enough for the conveyance of the people and the products of sparsely habited districts, through which these lines would pass. Doubtless a 2 ft. 9 in. railway would be enough for such requirements, not only at present but for many years to come; but how in the event of political difficulties? what if the troubles of war broke over the country? Could such railways as those proposed convey efficiently an army and its arms? Could men, and horses, and guns, and all the munitions of war be concentrated by the agency of an iron way 30 in. wide, or at that season of supreme requirement, would not the means be found inadequate, and the consequence of an unwise policy be keenly felt? These are considerations which do not come within the province of this article, which professed to deal simply with the question of cost; elsewhere we have dwelt upon other points of still greater importance, and shall proceed to the consideration of the other aspects of the subject.

NARROW GAUGE ROLLING STOCK.

Having dealt at some length with the relative costs of construction of railways of 3 ft. 6 in. and 2 ft. 9 in. gauges, we now propose to consider the carrying capacities and general features of the rolling stock which the two gauges would respectively accommodate. And here we find almost all the advantages on the side of the 3 ft. 6 in. gauge, without, so far as we can see, any corresponding disadvantages. In fact, it will, we think, be found, on investigation, that not only can the carrying stock for the wider gauge be built with as small a proportion of dead weight to paying load as that for the narrower line; but that in the former case there can be adopted a system of construction which affords far greater durability and facilities for economical maintenance than that which must be resorted to in the case of the 2 ft. 9 in. gauge. As to the further advantage which the 3 ft. 6 in. gauge possesses in affording facilities for the transport of troops and artillery, we shall speak presently, and we intend, in the first instance, to confine our attention to such rolling stock as is required for ordinary goods and passenger traffic.

And here it may be advisable that we should state a few facts bearing upon the question under discussion, which have not generally received the attention they deserve. In the first place, it has been generally assumed that the width of rolling stock which any line is capable of accommodating with safety, may be taken as about twice the gauge, and within the usual limits of gauge there is little reason to find fault with this assumption. But the advocates of the railways of extremely narrow gauge go further than this, and they argue that because in certain instances vehicles of a breadth exceeding twice the gauge have been used successfully on the 4 ft. 8½ in. lines, that, therefore, vehicles of proportionate width can be used with equal safety on a line having a gauge of but 2 ft. 9 in., or even less. This assumption, although at first sight a plausible one, is practically erroneous. If it were possible to make a line without inequalities, or if the inequalities of the line and the forces tending to produce oscillation could be reduced in the same proportion as the width of the gauge, then the proposition we have referred to would hold good; but these conditions, we need hardly say, are unattainable, and hence the assumption is inaccurate. The narrower the gauge the greater is the angle through which a vehicle is canted laterally through a certain depression or elevation of one of the rails, and the greater, therefore, is the inequality produced in the loads on the springs on opposite sides, and consequently on the two rails also. In fact, the narrower the gauge the greater the amount of lateral oscillation to which any given inequality in the line will give rise

and this is a point of especial importance in districts where, from the variations of climate, or other influences, the permanent way is liable at times to get more or less out of repair. It is not too much to say that the influence of width of rolling stock on its lateral stability has, in but too many cases, been entirely lost sight of by the advocates of lines of very narrow gauge, attention being solely paid to the height of the centre of gravity above rail level. This, however, is a subject of which it would be desirable to enter into a full consideration in an article like the present, and we, therefore, propose to return to it on a future occasion.

Another fallacy upheld by the advocates of very narrow-gauge lines is, that the narrower the gauge the less — almost in an equal degree — is the proportion of dead weight to paying load, whereas both theory and experience go to prove that so long as the amount of accommodation, and the strength to resist hauling and buffing strains, are constant the proportion of dead weight to paying load is almost, if not entirely, independent of the gauge. In other words, if the maximum weight of train in which a vehicle is to be used, and the maximum power of engine to the pulling and pushing of which it is to be subjected, be fixed, it matters but little, so far as the proportion of dead weight per ton of goods or per passenger carried, is concerned, whether the gauge of the line on which the vehicle is to run be 2 ft. 9 in. or 5 ft. 6 in. This, we know, is a statement which many advocates of very narrow gauge lines will be disposed to contradict flatly, yet it is a statement which is supported by ample practical evidence. We have before us particulars of the weights and carrying capacities of the Norwegian, Queensland, and other narrow gauge rolling stock, both for passenger and goods traffic, and with scarcely an exception these particulars prove the correctness of the opinion we have just expressed. Even in the case of the extremely narrow Festiniog Railway we find the dead weight of the passenger stock to be greater per passenger carried than many carriages running on the Continent on 4 ft. 8½ in. gauge lines, these latter carriages notwithstanding affording a greater number of cubic feet of capacity per passenger, and being mounted on 40 in. in place of 18 in. wheels. Similar evidence might be adduced concerning the goods-carrying stock were it necessary to do so; but we need merely refer to the carriages and wagons in general use on ordinary lines 15 or 18 years ago to prove that light stock can be made for the 4 ft. 8½ in., or a wider gauge, if the general nature of the traffic warrants its use.

We are willing to admit, however, that the wider the gauge the larger the carriage or wagon must be, to obtain the best results as regards the proportion of dead weight to paying load, or, to state the fact in other words, if the floor area and carrying capacity of a vehicle be fixed, there is a certain gauge of line for which such a vehicle can be constructed with less dead weight than for any other gauge. If, therefore, the nature of the traffic to be accommodated be such that small loads only can be obtained for the wagons, then it of course follows that small wagons should be employed, and it also follows, equally as a matter of course, that the gauge to be adopted should be such as is most suitable for the economical construction of wagons of that particular size.

So far the matter is straightforward enough; but it occasionally happens that the class of railway which it is desirable to adopt has to be determined, not merely from a consideration of the general nature of the traffic which will pass over it, but also from a consideration of traffic of an exceptional nature which the line may be called upon to accommodate. This, we consider, is particularly the case with the proposed new Indian railways. Constructed, as it is intended these lines shall be, to develop parts of the country at present furnished with very indifferent means of communication, they would become, in the event of war or internal disturbances, of immense military importance, and we consider it to be not merely especially desirable but absolutely essential that they should not be constructed to any gauge which does not afford ample facilities for the transport of troops, artillery, and military supplies. In this respect—as we pointed out in an article which appeared in the number of this journal for the 21st ultimo—the 3 ft. 6 in. possesses immense advantages over the 2 ft. 9 in. gauge, and, in fact, the advocates of the latter gauge have not yet shown how horses can conveniently and

safely be conveyed on it at all, unless by the adoption of vehicles of very great weight in proportion to the load carried. So long as the articles to be conveyed are goods which can be divided out into quantities of almost any required bulk, the question of size of wagon is a secondary one, so long as that size is not so great as to render it necessary to run wagons but partially loaded. With such goods, the fact of an additional quantity having to be conveyed by a train merely necessitates the addition of a certain number of wagons, and, so far, trains on a very narrow gauge line may be capable of conveying very large quantities of goods in bulk, so long as sufficient engine power is provided. But when the articles to be transported are *not* goods in bulk, but consist of military appliances, artillery, horses, or other things which must have a certain space afforded them, then the influence of the gauge in limiting the size of the vehicles becomes greatly felt; and if too narrow a gauge be chosen, it is certain that in some cases, not merely important inconvenience, but most disastrous consequences may be the result.

It will be seen from the facts we have stated, that the question of the best gauge to adopt in any particular instance is determinable, in a great measure, by the extent of floor area and carrying capacity which will be required in the rolling stock, and in the case of an extensive system of railways, such as it is proposed to construct in India, the *maximum* floor area and carrying capacity which will be required on any one part of the system has to be taken as the standard of measurement for the whole. The question of what this standard should be in the case of the secondary system of Indian lines is a matter for serious consideration, and instead of attempting to decide it in the present article, it may be desirable—for reasons which will appear presently—that we should say something of the rolling stock which it has been proposed to adopt for the 2 ft. 9. inch gauge.

The fact that Colonel Strachey, Colonel Dickens, and Mr. Rendel, in their joint report, have entered into particulars of the rolling stock they propose to employ on the 2 ft. 9 in. gauge in India—supposing that gauge ever to be adopted—enables us to discuss the question in a manner bearing directly on the point. Briefly stated, the particulars of the rolling stock the engineers just mentioned propose to adopt are as follows: For passenger service it is proposed to employ carriages 18 ft. 6 in. by 6 ft. wide, outside dimensions, and 6 ft. high internally, these carriages being divided, in the case of the third class, into four compartments, carrying *thirty-two* passengers, and, in the case of the second class, into three compartments, accommodating eighteen passengers. As regards first class, it is stated that the carriage may be specially arranged for carrying six passengers for short journeys, or three for long journeys, with luggage and servants; washing and closet accommodation being provided. The carriages are to have four wheels, 2 ft. in diameter, the axles being 3 in. in diameter, and having journals $2\frac{1}{2}$ in. in diameter by 6 in. long. The weight of such carriages, it is estimated, would not exceed $3\frac{1}{2}$ tons empty. The ordinary goods wagons it is proposed to make about 14 ft. long by 5 ft. 6 in. wide inside, the height, in the case of the covered wagons, being sufficient to give an internal capacity of 300 cubic feet. Such wagons, it is stated, need not weigh more than $2\frac{1}{2}$ tons, and it is intended that they should carry 5 tons of goods. The wheels and axles would be the same as for the carriages, and it is suggested "that the wagons should be designed, in the first instance, without bearing springs." Further, it is stated that the springs, both in carriages and wagons (when used on the latter), should be placed under the journals, so that the floors of the vehicles may be kept down to 15 in. above the rail level. The maximum weight on four wheels is taken as about 8 tons, or 2 tons per wheel, in the case of the carrying stock, but the weight on engine wheels is taken as 3 tons. The stock is to be fitted with combined central buffer and draw springs.

Such are the general features of the rolling stock which Colonel Strachey, Colonel Dickens, and Mr. A. M. Rendel recommend for adoption, and it is only reasonable to suppose that their recommendation had been very carefully considered by them before they embodied it in their report, and that it was founded upon the conviction that such stock was the best that could be placed upon lines of 2 ft. 9 in. gauge. This being the case, we

must own that we have been greatly surprised to find that a class of rolling stock embodying such numerous and serious practical defects should have been so recommended. We had imagined that even the 2 ft. 9 in. gauge could accommodate better wagons than Messrs. Strachey, Dickens, and Rendel propose to place upon it; but if these gentlemen are correct in their conclusions—and if their report be worth anything at all their conclusions should be correct—then we were in error, and the 2 ft. 9 in. gauge is a worse one for India than even we anticipated it to be.

What the leading objections to Messrs. Strachey, Dickens, and Rendel's rolling stock are, will be at once apparent to any one of experience in the construction of railway vehicles, if they will take the trouble to lay down an outline transverse section from the particulars we have given. Let us, for instance, in the first place, consider the wagon stock, and here we may at once discard the idea that a thoroughly serviceable stock of this kind could be made without bearing springs, as the authors of the report propose. Such an idea is suggestive of the influence exerted on the reporters' minds by the frequent inspection of Indian bullock wagons rather than of a careful consideration of questions relating to economical maintenance of rolling stock and permanent way—questions of especial importance in India.

The experience on some of the older colliery lines in the North of England, has proved how costly to keep in repair, and how unsatisfactory in every respect, this old class of springless wagons is, and we can, in fact, only regard with astonishment the proposal to use such wagons in India on lines where they would have to make long runs at speeds certainly reaching 20 miles per hour. Next, we find it recommended that the springs, if used on the wagon stock, should be placed beneath the journals, and this is a recommendation which we must also condemn. Springs so placed would require a more complicated attachment to the axle-box than if plated above the latter, they would be inconveniently situated for receiving their loads, and—the wheels being but 2 ft. in diameter—they would be so little above the rail level, that we feel assured that they would prove an endless source of trouble and annoyance.

These, however, are not the chief objections which may be urged to Messrs. Strachey, Dickens, and Rendel's rolling stock. If such a transverse section of the wagons as we have mentioned above, be laid down, it will be seen how difficult it would be to construct such stock of sufficient strength without incurring undue weight, and how inconveniently the floor area is broken up. The wheels being 2 ft. and the axles 3 in. in diameter, it follows that the height from rail level to top of axle will be $13\frac{1}{2}$ in.; but the height to floor level is but 15 in., and there would therefore be but $1\frac{1}{2}$ in. between the upper sides of the axles and the floor level. In other words, to allow for the wear of bearings and play of springs, the floor would have to be cut completely through from side to side for the whole length of the axle, or, practically, for the entire width of the wagon. In fact, the axles would form a complete barrier to the introduction of any diagonal bracing or of any longitudinal connection between the headstocks, unless such connection was placed above the floor level, in which case the floor level might as well have been raised at once. Again, the wheels, projecting as they would above the floor line, would have to be protected by arched casings about 8 in. wide by about 2 ft. 4 in. long, and 13 in. high, and we leave goods traffic managers to decide how far the loading of a wagon measuring 14 ft. by 5 ft. 6 in. would be effected by four such casings jutting up from the floor level.

Another important defect in the rolling stock we are considering, consists in the fact that its leading features are totally opposed to obtaining the full benefits attendant upon the adoption of the system of central buffers when properly worked out. The leading feature in that system is, that when properly developed, it enables all buffing strains to be transmitted direct through the centre lines of the carriages or wagons, whether the train be on a curve or straight line. In the case of a train with the ordinary system of side buffers being shunted round a curve, the main strain is transmitted through the soles or side framings of the vehicles on the inner sides of the curve; and as either side of a vehicle may on the

inside of a curve, both sides have to be strong enough to bear the maximum strain. In shunting over reverse curves, also, severe twisting strains are set up, but to these we need not refer here. In the case of the central buffers, on the other hand, as the strain is always transmitted along the centre lines of the vehicles, it is evident that all that is required, as far as that strain is concerned, is a central longitudinal framing, combined with diagonals capable of receiving the buffing and hauling strains, and distributing them to the rest of the vehicle. The rods serving as combined drawbars and buffer rods should, in fact, form a continuous "back bone" throughout the train, and the framing of the vehicle should be so arranged as to take off the requisite pulls and thrusts from this "back bone" in the best possible way. It is scarcely necessary to remark that the rolling stock proposed by Colonel Strachey, Colonel Dickens, and Mr. Rendel for the 2 ft. 9 in. gauge, utterly fails to fulfil these conditions. The direct connection between the centres of the headstocks being practically cut off by the axles, it follows that the thrust or pull applied at the centre of a headstock would have to be transmitted by that headstock, or some framing connected with it, to the side frames, and from these it would have to be transmitted by similar means to the centre of the opposite headstock. In other words, the buffing and hauling strains would have to be transmitted round through the side framing instead of passing direct along the centre line of the vehicle, and thus extra weight of framing would be required.

In the case of the carriage stock, these structural defects would be equally present, the height of floor from rail and the diameter of the wheels being the same as in the case of the wagon stock. The fact of the wheels projecting through the floor would, however, be of less consequence in the case of the carriages than in that of the wagons, as the seats may in some of the classes be arranged to cover them. As to the carrying capacity of the proposed carriages for the 2 ft. 9 in. gauge we need say little. Crowding four people, in an Indian climate, on a seat 5 ft. 6 in. long, for a journey lasting several hours, is suggestive of intense personal discomfort; but we suppose that the proposers will explain the matter by maintaining that the third class is used almost solely by natives, and by stating that natives generally are built upon narrow gauge principles. Let us hope that it is so, for the sake of Europeans. The accommodation in the second class, where it is proposed to place three psssengers on a seat is, of course, better; but we fear that in these carriages, with three compartments, the wheel casings projecting above the floor line will be found sadly in the way.

The fact appears to us to be that, with the idea, apparently, of obtaining a satisfactory amount of stability, the designers of this rolling stock have kept down the floor level to a height above rails involving an almost endless number of practical inconveniences of construction. Even as it is, the stability of the carriages as regards power of resisting lateral pressure is not what it should be. Including side frames and double roof, each carriage would expose a side area of about 125 sq. ft., and the centre of pressure for the wind would be about 4 ft. above rail level. The half width of the gauge being $16\frac{1}{2}$ in., and the weight of the carriages empty being $3\frac{1}{2}$ tons or 7,840 lbs., we have:

$$\frac{7840 \times 16.5}{125 \times 48} = \frac{129360}{6000} = 21.56 \text{ lbs.}$$

as the pressure of wind per square foot required to just balance the righting moment of the carriage when empty. This stability certainly does not appear to us to be sufficient for Indian lines.

Another defect in the rolling stock we are considering is that the axle-boxes would be almost inaccessible, and this would be especially the case with the wagon stock, where no openings in the floor would be available for the purposes of oiling or inspection.

The stability of the wagons proposed by Messrs. Strachey, Dickens, and Rendel is, no doubt, ample, but it has been obtained, as we have shown, at a terrible sacrifice of other essential features. Considering the closeness of the axles to the floor, and the probable lightness of the upper covering, the centre of gravity of one of these covered wagons when empty would probably be about the floor level; and as the load would be about 4 ft. high above floor, and would, it is stated, amount to twice the weight of the wagon itself, the centre of gravity of the wagon and

load would be about 2 ft. 7 in. above rail. This would give an angle of stability of about 55°. On the 3 ft. 6 in. gauge, wagons possessing the same angle of stability, the same floor area, and of the same dead weight and carrying capacity, could be built with the floor clear above the wheels, with continuous drawbars, with springs above the axle-boxer, and with the latter thoroughly accessible. How much more economical such wagons would be to work and keep in repair than the abnormal stock, of which we have given the particulars, we leave our readers to imagine.

Taking everything into consideration, we believe that the rolling stock proposed by Colonel Strachey, Colonel Dickens, and Mr. Rendel, will be generally condemned by men of experience in railway matters, and we think with good reason. If such stock is the best which can be placed on the 2 ft. 9 in. gauge, then the less we hear of that gauge being advocated for India the better. If, on the other hand, better rolling stock can be designed for lines of such a gauge, why was it not proposed by the advocates of that gauge in their report? In any case we do not see how horses, artillery, or military stores generally, can be transported on the 2 ft. 9 in. gauge unless it is in specially constructed vehicles utterly unfit for the purposes of ordinary traffic; or, in other words, if the 2 ft. 9 in. gauge lines are to have that efficiency in a military sense which it is all important that railways in India should have, then they must be provided with a special class of "military" rolling stock always maintained ready for use, yet never available for ordinary traffic. A very desirable state of affairs this for cheap railways. On the 3 ft. 6 in. gauge, on the other hand, vehicles could be readily constructed available for both military purposes and ordinary traffic.

We have in the foregoing article confined our attention chiefly to some points of comparison between the rolling stock of the 3 ft. 6 in. and 2 ft. 9 in. gauges; but we have far from exhausted the subject, and there are in fact many matters connected with it on which we have not touched at all. Under these circumstances, we intend to speak further of the matter in a future number. Before closing this article, however, it is only right that we should remark that the 2 ft. 9 in. and the 3 ft. 6 in. are not the only narrow gauges proposed for India. Mr. Fairlie is advocating the 3 ft. gauge, and the employment on it of rolling stock of much a lighter character than that proposed by either Mr. Fowler, or Messrs. Strachey, Dickens, and Rendel. Mr. Fairlie, indeed, advocates employing for the transport of cotton, platform wagons of very simple construction, weighing but 1 ton, and carrying a 3-ton load. These wagons would have four wheels, and the weight per wheel would thus be but 1 ton. Mr. Fairlie maintains that the use of such stock would offer great advantages in consequence of the ease with which it could be handled at stations by manual labor, and that there is much in this fact we are willing to admit. We must, however, defer saying any thing more on this point until we can speak at length of the other matters to which we have referred.

THE LATEST RESULTS OF SEWAGE IRRIGATION.

From "The Engineer."

If a principle be in itself sound and susceptible of a thorough practical application, it is to be expected that when it has been submitted to a fair trial it will afford from time to time increasing proofs of its value and reliability. There are very few projects or undertakings, however visionary and delusive they may be in reality, which may not by ingenious artifices and preconcerted arrangements appear to give at first satisfactory results. An inventor or patentee is always ready—sometimes a great deal too ready—to believe in the offspring of his own creative genius; and it is not surprising that when he is surrounded by friends and well-wishers the belief should be infectious. It is difficult in some instances for even those whose better judgment may have a contrary bias, to escape altogether from the influence of the contagion. But however successful ephemeral enterprises may appear to be when tried at intervals and in a kind of spasmodic manner, they are

sure to fail before the searching test of time. They are, in fact, incapable of prolonged activity, and, like certain descriptions of clocks and watches, may be said to have no maintaining power. People are very apt to decide upon the truth or falsehood of a principle from the results of one or two isolated experiments, which, owing to some trifling omission or error usually accompanying preliminary trials, may possibly be altogether inconclusive. Every one knows the meaning of the phrase "to get things into working order," and it is not until things are in working order that any fair criterion can be afforded of the correctness or incorrectness of the principle upon which they do work. We make these remarks in deprecation of the hasty judgment that persons are so prone to form upon very slight grounds, and *apropos* of the subject we may allude to another point. A common practice with inventors and other interested parties who have a patent to introduce, is to demonstrate its future success *in multo* by that attending its experiment *in parvo*. In other words, they construct a model of the invention, and provided it works well they predict that it will do the same on the largest scale. Doubtless, in some instances, the prediction is verified, but in far more it is falsified. It must not be forgotten that models are, after all, little better than toys, and we know a great number of applications of well recognized principles upon this scale which are not capable of extension upon a larger. On the other hand, when any principle has been steadily and perseveringly tried for a period of some years, and has given undeniable proofs of being completely reducible to practice, and, moreover, convertible into a method of making money, it is time to believe in its integrity, and to accord to it the importance which is its due.

At present there are probably fewer opponents to the principle of the utilization of sewage by irrigation than there formerly were. Without wishing to claim any superiority on its behalf over any of the other systems proposed for effecting the same object, it must be confessed that the latter have not come out of the experimental ordeal to which they have been subjected so well as they ought to have done, or so well as they proposed to do. Many towns which have given the various deodorizing and disinfecting schemes a fair trial, have abandoned them in despair after spending upon them very considerable sums of money. There is no instance where the irrigation system has been tried and abandoned. Whenever the necessary quantity of land has been obtained, the works constructed, and the irrigation started, the success has been too marked ever to cause any regret on the part of the promoters of the undertaking. In consequence of the unsettled state in which the sewage question has been for some years past, and the conflicting opinions expressed by many eminent authorities respecting the best means of accomplishing its utilization, the real matter at issue has been in abeyance, and comparatively little or nothing has been effected. The time which should have been devoted to solving practically this great national problem has been wasted in the more exciting, but infinitely more expensive employment of quarrelling and litigation. The last five years have been especially prolific in the petitioning for, the granting, and occasionally the enforcing of injunctions against contumacious public bodies and private individuals who would persist in polluting streams by discharging sewage and refuse into them. It is true that the sewage farm at Croydon has been at work for some time, and the Lodge Farm at Barking also, but the former of these until very lately has not appropriated any appreciable quantity of its area to other than grass crops. So far as these are concerned we shall not include them under the heading of this article, as there can be no possible difference of opinion respecting the unprecedented results obtained by treating them with sewage. From Craigentinny downwards the success in this particular crop has been universal. But, although there is nothing new to chronicle regarding the continued fertility of grass lands so treated, yet the last year has not passed without contributing some valuable information in many ways. Any one who has carefully perused the various reports, pamphlets, and descriptions of experiments that have appeared at intervals, cannot fail to arrive at the exceedingly satisfactory conclusion that the value of sewage is becoming more and more appreciated every day. The whole subject is, moreover, viewed in a totally different

light to that in which it formerly was, and is at last receiving that scientific consideration and practical attention which ought always to have been bestowed upon it. If in some cases, where the principle of irrigation is adopted, there may seem to be still rather an indiscriminate application of the fertilizing fluid, it must be kept in view that this probably cannot be avoided. The difficulty of procuring a sufficient area of land adequately to effect the utilization is so great, that parties have no alternative but to take what they can get, and be thankful even for that much. Under these circumstances, it is not surprising that the crops should be frequently overdosed. The fact that the sewage must be disposed of at regular periods leaves no other resource available than to turn it on to the land at those times. Hence the necessity of always maintaining a considerable portion of a sewage farm in grass, as that crop will take a larger quantity of the fertilizer and at much more frequent intervals than any other.

In one respect the last season has been singularly well adapted to display the vicissitudes under which the best systems of farming and agriculture labor. It has demonstrated that something else is necessary besides mere irrigation to produce abundant crops of rye and other grasses. The prevailing opinion at the Lodge Farm was that during a season of excessive drought the command of sewage would enable large crops of grass to be grown on irrigated land, while there would be little or no produce upon land not so advantageously situated. This expectation was partially disappointed. In consequence of the drought more frequent applications of sewage were made, but they were not attended with a proportionate increase in the crops. This result is particularly worthy of attention, as a reference and guide in cases of future occurrence of a similar character. It was not owing to the land having been too often planted with grass in successive seasons, for it had the year previously been sown with root and other crops. At present the only solution offered for the fact is that it must be attributed to the great dryness of the air, and the hot gravelly description of the soil, which probably became "burnt" by the fierce action of the sun upon it. This supposition is borne out by the circumstance that, as the weather became cooler, the crops improved visibly, and recovered, to a great extent, their normal appearance and condition.

Passing to a consideration of other crops, we find the drought produced no evil effect whatever, but, on the contrary, established the great advantage that accrued from having a command of an unlimited supply of so powerful a liquid manure. Hitherto there has been only one crop that evinced a dislike, if the term may be used, to being treated with sewage. It required at first a good deal of careful management and skill successfully to apply sewage to onions, but the difficulty has been completely overcome. Last season, owing to the drought, onions failed in the neighborhood of the Lodge Farm, while on the farm itself a finer crop has been realized than was ever grown previously under any condition of ordinary cultivation. It appears advisable in some instances to use a little farm-yard manure upon this crop as well as the sewage, but when the treatment is better understood the necessity for this will probably cease. The value of sewage, not merely as a fertilizer, but as a simple irrigator, was very conclusively shown during last season at the farm under notice. It was intended to leave a crop of oats without any dressing of sewage, on the supposition that the soil had been so thoroughly saturated with it that it contained all the fertilizing ingredients necessary for the full development of the cereal. No doubt this was the fact, and it is thus that poor soils may after some years be converted into rich ones, and as it were be completely regenerated; but the weather turned out so very hot and unfavorable that it was necessary to apply the sewage to save the crop. Had there not been a supply available at the right time the crop would have been lost, not for the want of manure, but of water. A similar course of action was followed in the case of a potato crop. It is well known that soils have a power of husbanding or storing up the fertilizing ingredients in them, until they are drawn forth or extracted from them by the wonderful assimilating energy with which all plants are endowed, and by virtue of which they can select and reject the food offered to them with as much discrimination as the most

accomplished *gourmet*. It will require some few years more before it can be satisfactorily proved that soils can be permanently manured by the application of sewage, and that, therefore, for a certain time they will not need a further application of it, except in seasons of drought, when it will be used for simple irrigation purposes. Should this eventually ensue, it will necessitate the consideration of the whole question on a much more extended scale than has hitherto been adopted. Sewage irrigation would then assume a range equal to that occupied by our gas and water services. It would probably confound many old-fashioned farmers, who have puzzled their brains over the theory of the rotation of crops, to hear of a splendid yield of strawberries following a fine crop of onions upon the same piece of land.

The real lesson to be learned from the results of the application of sewage last season is very instructive. It teaches us that we are slowly but surely acquiring the knowledge necessary to enable us to deal with the question in a manner that will prove a financial success, and thus remove the only barrier against the adoption of the system. It is only now that some insight has been gained into the action of this fertilizer upon different crops, and how it is indispensable to treat one very dissimilarly to another, in order that equally good results may follow. There is a vast deal to be learned upon this point yet. At present we know that a particular course of treatment which will prove eminently advantageous to one crop will almost ruin another, but we do not yet know precisely the best course to adopt in every individual instance. There is little doubt, however, that we are in a fair way to obtain this information, and it will be our own fault if we are not soon in full possession of it.

SZERELMEY'S PRESERVATIVE FOR STRUCTURES.

From "The Railway News."

A company has been formed, with a small amount of capital, for the purpose of carrying out a number of inventions and discoveries of Colonel Szerelmey, having for their object the preservation and induration of stone, brick, cement, timber, iron, and metal work, and almost every kind of mineral and vegetable substances. The principal ingredient employed is a material to which the old Greek name of Zopissa has been applied; it is a material which can be obtained in large quantities, at a trifling cost, and its employment for the purposes named, while perfectly effectual, is at the same time exceedingly profitable. The first time that the substance was heard of and practically employed in this country was during the building of the Houses of Parliament, when its application was strongly recommended by Sir Charles Barry to certain portions of the stonework of those buildings, which even at that early stage showed signs of decay. It was also applied, under the direction of Sir Charles Barry, to the gilding of the Victoria and Clock Towers. The experiment of introducing gilding for decorative purposes in London being then regarded as a novelty, it was deemed advisable, if the gilding were employed, that it should, if possible, be protected from the corroding effects of the London atmosphere. The gilding, treated with a preparation of the Zopissa, has withstood most successfully the influences of the atmosphere, as also the portions of the masonry on the river front which were treated with the Zopissa composition. These portions are still perfectly hard and crystalline, and their granulated surface is wholly unimpaired, while in other portions of the building, which have not been similarly protected, the stone masonry is rapidly decaying, and the finer portions of the carving are gradually mouldering into ruin. To such an extent is this work of destruction going on that Mr. Barry, the late architect, considered it necessary that all the decayed portions of the stone should be cut out and fresh pieces inserted in their place—a work which would probably have afforded employment for architects and masons for the next half a century. A more simple and more economical, and, as we are informed, an equally efficient remedy against decay, is provided by the application to these parts of the building

of this Encaustic Zopissa, which has during 12 years shown its efficacy in arresting decay. This course has at length been decided upon, and the preservative composition is now being gradually applied to various portions of the Houses of Parliament. The iron roofs of the New Palace at Westminster were coated with the composition some months since, the experience of 12 years having proved its value for this purpose on other parts of the roof and ironwork. A large number of public and private buildings, including portions of the Bank of England, St. Paul's Cathedral, in London, and many mansions and seaside residences, have been treated with the composition, and with satisfactory results. The preservative process of Col. Szerelmey may be applied to the following purposes:—For indurating stone, brick, and cement; for preserving metal of all descriptions from decay; for preserving timber employed in roofs of buildings and railway stations; for preserving railway sleepers; for protecting ships' bottoms, being a substitute for copper sheathing, and applicable to iron vessels; for hardening and rendering waterproof plaster of Paris ornaments and various descriptions of porous substances; and for rendering waterproof all descriptions of textile fabrics. The application of the process to the preservation of railway sleepers has, we are informed, been eminently successful, although it has not yet been introduced upon any railway. Some sleepers which were prepared 16 years since are now lying on a piece of waste land, the property of the London, Chatham, and Dover Railway, near its station at Pimlico, and are now in a perfectly sound condition. Should the composition possess all the qualities claimed for it, the new company would find in this item alone a very large and no doubt profitable amount of business on the railways of this and other countries.

The practical application of the preservative processes to each of these materials to such an extent as will enable the inventor to meet the demand, is wholly beyond the means of ordinary private enterprise, and, as we have already stated, a company, having a board of directors who have fully satisfied themselves of the merits of the inventions, as well as the profitable nature of the business, and who are fairly entitled to the confidence of the public, has been formed for the purchase of all the rights and interests of the inventor in his existing contracts — including the supply of the composition to the Houses of Parliament, the good will of the existing business, plant, and manufactory, and everything requisite for at once carrying on a business, the profits of which, the directors state, "will be such as to restore to shareholders the whole capital of the company within a very few years." For obvious reasons, they do not state publicly in their prospectus the profits arising from the manufacture of the materials, but a very good indication of this is afforded by their cautious statement that they are such as to admit of the return of the whole capital in a very few years. The capital of the company is £50,000, of which £30,000 only is offered for subscription, Colonel Szerelmey showing his confidence in the prospects of the company by taking at the option of the directors one-half of the purchase money in shares, which do not carry interest until 10 per cent. has been paid on the entire capital of the company, and the payment of other portions is also made contingent upon the snccess of the company's operations.

It seems that the big Sheffield steel ingot described in our November issue was but a small affair. A correspondent of the "American Railway Times," says of the productions of Krupp's establishment at Esson: To call a single casting of 35,000 lbs. "the largest ever made" proves how far England has been left behind in steel manufacturing. If this statement had been made 15 years ago, it would have been correct at that time, but in 1862 Krupp had already sent to the London Exhibition a cast steel ingot of 40,000 lbs. weight. The inner tube of an 11-in. gun requires a solid casting of 70 to 75,000 lbs., and more than 50 of such guns have left the works this year. Krupp's 1,000 pounder steel gun exhibited in Paris in 1867 weighs 100,000 lbs. in the finished state. What castings are employed for such heavy masses we leave to the consideration of the writer of the above mentioned article, hoping that it may increase his knowledge in such matters.

The first railway in America was commenced with 3 miles at Quincy, Massachusetts, in 1827.

THE INCRUSTATION OF BOILERS.

From "Engineering."

It is somewhat curious that while the complaints of inconvenience resulting from the incrustation of boilers are so numerous, the attempts to avoid those inconveniences by providing boilers with pure water should be so few. Boiler owners are ready enough to patronize patent fluids, compositions, and a variety of nostrums having for their object the prevention of incrustation, but we rarely find efficient appliances in use for purifying the water before it enters the boiler, and thus rendering such doctoring as we have just referred to unnecessary. It must not be supposed, from what we have just said, that we object *in toto* to the employment of chemical means for preventing incrustation ;—on the other hand, we believe that such means may be employed with great advantage in a vast number of cases ; but we consider, first, that chemical "anti-incrustators" should not be applied indiscriminately and without a knowledge of the impurities which it is desired to remove ; and, second, that as far as possible the purification of the feed water should be effected before it enters the boiler, and not in the boiler itself.

Those members of the Institution of Mechanical Engineers, who were present at the reading of Mr. E. B. Marten's interesting paper on boiler explosions, during the meeting at Nottingham last autumn, will remember that the matter to which we have just alluded was brought prominently forward in the discussion on that paper ; and to some of the facts stated in this discussion we intend in the first place to direct attention, believing as we do that they deserve to be more widely known than they will perhaps become through the medium of the Society's "Transactions." Many of our manufacturing towns are, as is well known, very badly off for water available for use in boilers, and pre-eminent amongst these towns is Oldham. Oldam stands on elevated ground, and is supplied with water conveyed a considerable distance from boggy ground at a higher level, and the supply is moreover so limited, that at Messrs. Platt's works the foul water from the drains has to be used for the boilers and for condensing purposes. Under these circumstances it has, of course, been necessary to provide means for purifying the water, and these arrangements were described by Mr. W. Richardson in the course of the discussion we have referred to. In the first place, to make the water fit for use for condensing purposes it is made to pass in succession through 3 settling reservoirs, the second reservoir receiving the overflow from the first, and so on. The injection water is taken from the last reservoir, and the waste water from the hot well flows back into the second. The boilers are fed from the hot well, the feed being filtered on its way to the boilers. The filters consist of a number of vertical cast-iron vessels strong enough to stand an internal pressure of 100 lbs. per sq. in, or 25 lbs. per sq. in. more than the boiler pressure, these vessels being each provided, at about the middle of its height, with a perforated plate or grating, on which a layer of calcined bones, about 3 ft. in thickness, is placed. The water is forced by the feed-pump up through these bones, and is led off from the top of the filter to the boiler. It was stated by Mr. Richardson that the water in the hot well is so filthy that the bones become choked with dirt in about half a day's working ; and each filter is therefore cleansed twice a day—namely, during the dinner hour and at night—by blowing steam downwards through it. By this simple means the bones are thoroughly cleansed and the filters made ready for work again. The results obtained by the use of the plans we have described have been of a very satisfactory kind, and the whole arrangement is so simple as to commend itself at once to those suffering from the use of very dirty water.

In the case of their non-condensing engines Messrs. Platt employ an arrangement of feed-heater in addition to the filters, so as to obtain a supply of hot clean water. For this purpose the water is conveyed from the last settling reservoir into a covered tank, 6 ft. deep by 6 ft. 3 in. wide, having the water level regulated by a ball-cock, so that it is maintained 9 in. below the cover. At one end there is fixed on the cover a vertical cylindrical feed-water heater, 12 ft. high by 2 ft. 6 in.

in diameter, this heater being traversed by tubes, whilst at the opposite end of the cover stands a vertical pipe, 20 in. in diameter, 30 ft. high, and open at the top. By means of a circulating pump the water is lifted from the cistern and made to fall in a shower down the pipe just mentioned, meeting in its course the exhaust steam from the engines, which is made to pass down through the tubes of the feed heater, then over the surface of the water in the tank, finally rising up through the vertical pipe, to be met by the falling shower. By this arrangement the water in the tank is heated to about 170°, at which temperature it is taken off by the feed pump and forced, first through a bone filter, and then through the feed-water heater to the boiler, which it enters at a temperature of about 120°. Mr. Richardson stated that, by the employment of this arrangement, an important saving had been effected in fuel and labor, and the boiler, which formerly had to be cleaned out every week or fortnight, now has to be cleaned at holiday times only.

In many cases trouble is experienced from the presence of an excessive quantity of bicarbonate of lime in the water used for feeding boilers, and in such cases Clark's process for purifying the water might frequently be resorted to with advantage. It is very usual to speak of the presence of large quantities of carbonate of lime in water, but this is an error, the carbonate of lime being almost insoluble, a fact on which Dr. Clark's process is founded. This process consists, as many of our readers are, no doubt, aware, in treating the water containing the bicarbonate of lime which it is desired to remove, with lime water, or a kind of milk of lime, the effect being that the lime thus added deprives the bicarbonate of a portion of its carbonic acid, thus converting it—and being itself also converted—into carbonate of lime, which, being almost insoluble, is deposited. In the course of the discussion, to which we have already referred, Mr. Lewis Olrick mentioned a case in which Clark's process had been successfully applied, at Bury St. Edmund's, to the purification, for boiler-feeding purposes, of water containing 30 grains of bicarbonate of lime per gallon. Mr. Olrick stated that in this instance the water is pumped into a tank 6 ft. high by 2 ft. in diameter, where it is mixed with lime water suitably prepared and supplied from a smaller tank. The effect is the deposition of the greater part of the lime in the mixing tank, the water drawn off being subsequently filtered by passing slowly upwards through another tank partially filled with small pieces of coke. The coke is contained in a loose cylindrical casing within the tank, so that it can be conveniently renewed when clogged with lime. This apparatus has been at work over two years, and it has been found to be very effectual in keeping the boiler clear of all hard scale.

Although, however, the adoption of such methods of purification as those above described will be found exceedingly beneficial in a vast number of cases, yet we believe that ultimately it will be acknowledged that the only true remedy for bad water is the adoption of surface condensers. The experience of our marine engineers has now thoroughly proved the advantages to be derived from this system of condensation, and the practical difficulties which so long delayed its adoption are now generally understood and the means for overcoming them known. In applying surface condensers to land engines arrangements will in many cases have to be adopted differing greatly from those employed at sea. The condensing water available on land, in many instances is of such an impure kind that such condensers as are fitted to marine engines would be clogged by it in less than a week. In these cases the condensers should be so arranged as to permit of all parts being thoroughly accessible, and they should be made to stand rough work. Where the condensing water contains much floating matter, and where appliances for purifying it cannot conveniently be provided, evaporatvie surface condensers are particularly suitable, as they can be made without any passages to clog up, and with all the surfaces in contact with the condensing water fully exposed at all times. Condensers of this class, in fact, have been far from receiving the attention to which their simplicity and the comparatively small amount of water with which they can be worked entitles them. Probably the chief objections to them are their cost and the space they occupy; but the first can scarcely be considered excessive when their advantages are taken into consideration, and by a little manage-

ment they can generally be arranged to occupy space which would not otherwise be turned to account. In some cases also air surface condensers may be employed with advantage, although from the great amount of surface they require, condensers of the evaporative class are preferable whenever the water for working them is obtainable.

Even what are ordinarily called non-condensing engines may be advantageously fitted with condensers in many instances, these condensers having only enough surface to condense the steam into water at 212°—very much less surface being required to do this than to form an efficient vacuum. Messrs. Perkins have adopted this plan extensively for engines supplied with steam by their water-tube boilers, and their example is well worth imitating in numerous instances where ordinary boilers are used, but where good water is not to be had.

In instances where, from some cause or another, surface condensers cannot be applied, and where, notwithstanding bad water being used, elaborate arrangements for treating it cannot be employed, attempts should still be made to cause the water to deposit the greater part of its impurities in a separate receiving vessel, in which the water may be heated under pressure, rather than in the boiler itself. The boiler should only be allowed to receive with the water such matters as cannot practically be removed elsewhere, and if this result was generally sought after we should hear little of overheating, distorted flues, and a host of other troubles which now annoy the boiler proprietor, to say nothing of the more serious failures which are but too frequently caused by incrustation.

The subject is an important one, and we intend to have more to say about it on an early occasion.

NITRO-GLYCERINE AND GUN-COTTON.

From "Nature."

It may be of some interest at the present moment to give a brief summary of certain comparative experiments undertaken with nitro-glycerine and gun-cotton, with a view to ascertain their respective destructive nature and safety of employment as industrial or warlike agents. As it is occasionally inconvenient to employ a material of this kind in the form of a liquid, a modification of nitro-glycerine, known as dynamite, and which is simply powdered glass or sand saturated with the explosive, was applied in the experiments; the force of the dynamite very nearly equals that of nitro-glycerine, and is of course much more readily handled than the liquid explosive itself. Nitro-glycerine or its compounds are the only agents of this nature that can compete in any way with gun-cotton, either as regards its igniting force or cost of production; and for this reason the experiments with these two materials have been watched with particular interest by military men, and have indeed formed the subject of a special report recently submitted to Government by the Committee on Explosives.

The explosive force of detonated dynamite and the Abel gun-cotton, as the compressed or pulped form of this material is termed, was considered to be about equal, and on this account the investigation was more particularly confined to the methods of ignition of the two substances. Professor Abel had already shown, in his communication to the Royal Society, that gun-cotton detonated only under certain conditions, and but by the instrumentality of particular agents. And here it should be borne in mind that there exists a very great difference between the detonation and inflammation of gun-cotton. A block of the compressed material, for instance, may be set fire to in an ordinary room without the semblance of danger—the cotton burning vigorously and rapidly, it is true, but without any approach to explosion; ignited, however, by means of a small quantity of fulminate of mercury or fulminate of silver, the explosion is of the most violent description. The fulminates above-named are the only ones found to bring about the ignition of gun-cotton in this truly terrible manner; iodide of nitrogen fails to have any effect thereon, and chloride of nitrogen

is occasionally successful in doing so, provided it is employed as a primer in sufficient quantity. While, however, gun-cotton is thus very difficult of detonation, except by the use of special means, nitro-glycerine, or dynamite, readily detonates under ordinary circumstances. That is to say, not only do the fulminates above-mentioned secure its ignition, but percussion-cap and other compositions, as also a sharp concussion, inevitably bring about its combustion.

An interesting experiment will indeed show at once the marked difference between the two explosives. Two wooden boxes were filled with compressed gun-cotton and dynamite respectively, and placed in a suitable position at a rifle range, where they could be hit with certainty by small arms. A bullet was fired at each box, and the results were very conclusive; the dynamite detonated in a terrible manner at the shock, while the gun-cotton was merely inflamed, and burned in a rapid but steady manner.

It was further found that in order to secure certain and perfect detonation, it was always necessary to employ a much larger and more powerful detonating fuze (one containing a large amount of fulminate) for the explosion of gun-cotton than was required for nitro-glycerine, proving beyond doubt, therefore, that the latter is much more readily ignited than the fibrous material. This is of course a great safeguard, and, added to the fact that under many circumstances of accidental ignition gun-cotton inflames harmlessly and does not detonate, speaks much in favor of proxiline. Indeed the use of nitro-glycerine can, according to our best authorities, be applied only within very narrow limits, as, for instance, for blasting and mining purposes, and its employment even in this sphere necessitates very careful supervision.

From this it will be at once seen that the recent prognostications of several of our war correspondents, that the Prussians intend to employ dynamite shells in the bombardment of Paris, must be entirely without foundation, for, according to the results obtained by the Explosive Committee in this country, the discharge of a nitro-glycerine shell from a gun would be of itself sufficient to bring about the immediate bursting of the arm itself.

GOOD AND BAD STOKING.

From "The Engineer."

It is curious, but none the less true, that the influence of the stoker on the economy of fuel is systematically neglected by engineers. In estimating the relative merits of different engines, it is always assumed that the fuel is burned under conditions with which the men who supply coal to the furnaces have nothing whatever to do—in short, that any man who can throw coals on a fire and keep his bars clean must be as good as any other man who can do, apparently, the same thing, and, apparently, nothing more. But it is certain that this conclusion is totally erroneous. The steam engine has been so far improved that it is only by the utmost refinement of skill that small economies can be effected in the consumption of fuel; and the brains of the best men of the day are taxed to the utmost to design these refinements, and apply them properly to their intended purpose. But all the while the influence of the skill of the stoker is overlooked, and, at the same time that we are moving heaven and earth to save an ounce of coal per horse per hour, we employ men without question who may waste through ignorance ten times as much fuel as we try to save, or neglect men who might save ten times as much by *their* skill as the engineer can hope to save by *his*. This matter was never brought into a clear light until the recent engine trials at Oxford, when, for the first time, the judges measured the water evaporated. The results were startling in the extreme. Frederick Moody, one of the best firemen in England, succeeded in obtaining an evaporation of 9.37 lbs. of water per lb. of coal from the Society's boiler, the Reading Ironworks Co.'s engine running for 3 hrs. 19 min. Messrs. Marshall's man got from the same boiler, and with the same coal, an evaporation of only 8 lbs. of water per lb. of coal. Messrs. Marshall's engine

ran but 2 hrs. 44 min., and consumed 5.18 lbs. of coal per horse per hour. If Moody had fired for Messrs. Marshall with as much skill as he fired for the Reading Iron Company, the consumption of fuel would have been but 4.22 lbs. We thus find that a difference in the skill of two stokers, both very good—Messrs. Marshall's man was far above the average of stokers—may cause a difference of nearly a pound of coal per horse per hour in the relative consumption of two very good engines. Surely it is time to think of the stoker when we find that he can save or waste 20 per cent. of the whole weight of fuel required to do a given amount of work. We have gone on improving boilers and engines for years—suppose that, just for a change, we try to improve the stoker.

Mr. Aveling, of Rochester, is the first in the field in this direction, and the results he has already attained are sufficiently curious. Mr. Aveling, some time ago, initiated a system of giving prizes to be competed for by all portable engine drivers in Kent who chose to enter the lists. The conditions of the competition were very simple. An engine fitted with a brake similar to that used by the Royal Agricultural Society, was handed over in succession to the different competitors, with a stated quantity of coal and wood—the driver who ran the engine for the greatest mechanical time with the least consumption of oil got the first prize, and

Driver.	Water.	Oil.	Time run.			Revolutions.
		oz.	h.	m.	sec.	
Thomas Turner	even	1½	0	59	45	7747
William Easdown	¼	3	1	3	53	8243
W. Tuck	⅜	1¾	1	4	54	8374
E. Pantoney	1⅜	1	1	1	25	6917
W. Holness	½	2	0	54	5	6733
T. Hadlow	¾	2	1	1	15	7553
A. Sampson	⅜	2½	0	59	40	7618
James Payne	1⅜	2	1	0	0	7025
W. Black	½	1	0	58	55	7346
G. Dalton	¼	1½	0	57	30	7446
J. Philpott	⅜	3¼	1	0	0	7534
W. Stone	1-16	1½	1	5	0	8470
R. Stickle	even	3	1	0	0	7717
[Not in Competition.						
W. Ilman	¼	1½	1	7	20	8885

so on. The trials were, in the first instance, strictly private in the sense that we believe the money for the prizes was supplied by Mr. Aveling out of his own pocket. We are delighted to find, however, that a scheme so admirable in itself has been growing in popularity, and was adopted at the last meeting of the Faversham Agricultural Association, at Faversham. The Society offered three prizes: First, a silver medal and £3; second, a silver medal and £2; and third, £1. These prizes were to be awarded to the driver who should obtain the greatest number of revolutions with the least consumption of oil and fuel. Thirteen competitors entered, and the trials, which excited considerable interest and attracted many agriculturists of the district to witness them, took place in the cattle market at Faversham, commencing on Monday week and being continued on the two succeeding days. The engine used for the trials was a portable of 8-horse power, to which was attached a friction brake carrying a load equal to a duty of 8-horse power. Each driver was supplied with 84 lbs. of coal and 8 lbs. of wood. The height of water in the boiler was noted, and the difference in level at the conclusion of trial calculated at the rate of 500 revolutions per inch. The oil used was also accurately measured, the lubricators being filled up before the commencement of trial by the driver who had just finished his run.

As regards the water, it will be well to explain that in the foregoing tabular statement the word "even" means that the water was at the same level at the end of the run as at starting. The figures show in inches or parts of an inch how far the level differed at the end of a trial from the level at the beginning. If a man concluded with an inch of water too much, he was credited with 500 revolutions. If he concluded with an inch of water too little, 500 revolutions were deducted. W. Illman, who did not compete, is the boy who so ably handled Messrs. Aveling and Porter's portable steam crane at Oxford, and elicited the commendations of our special correspondent. Although only 15 or 16 years of age, it will be seen that a judicious education, and a natural turn for his calling, has enabled him to obtain a higher duty than any of the competitors.

The true importance of the results obtained will be best understood when put into the shape which Mr. Aveling gave them in a speech which he made after the dinner, with which the meeting terminated: "The best driver obtained 8,885 revolutions of the brake, which was equivalent to a consumption of 82½ tons in 250 days; the worst driver obtained only 6,733 revolutions, equivalent to a consumption of 104 tons of coal in 250 days; the difference being 21½ tons per annum, or a value of £21 10s. The smallest quantity of oil used was 1 oz., equivalent to a consumption of 17 gallons in 250 days; while the largest quantity of oil used was 3¾ oz., equivalent to a consumption of 65 gallons in 250 days; so that the difference was 48 gallons, or a value of £13 4s. The results were as follows: Saving of coal per annum, £21 10s; saving of oil per annum, £13 4s.; total, £34 14s. Besides this, it must be noted that in ordinary work the worst driver would show a much worse result in comparison with the best. He thought these were questions involving either economy or waste, which to agriculturists were of great importance, and deserved far more attention than was generally paid to them."

We go further than Mr. Aveling, and hold that these results deserve the best attention, not only of agriculturists, but of the whole community of steam users. We trust that similar trials of fuel may be inaugurated by the Royal Agricultural Society at their next meeting, and it would be very well worth the while of the principal steam users in our great manufacturing districts to hold a competitive examination, so to speak, of stokers each year. We feel convinced that more fuel would be saved by encouraging good stoking in this way than is likely to be effected by any improvement which the steam engine is now capable of undergoing. The thanks of the community are due to Mr. Aveling for his persistent efforts to improve the *status* of stokers.

In conclusion, we may point out that the anomalous results obtained from boilers of the same type, under different circumstances, are probably due to varying skill on the part of the stokers. No trial can in future be considered satisfactory which does not take this consideration into account.

THE RAILROADS AND THE STATE.*

After referring to the present condition of the roads of Massachussets, giving the usual statistical information, the Commissioners add:

The remainder of this report must be devoted to a discussion of what may not incorrectly be termed the general railroad problem; which includes the relation of the roads, both materially and politically, to the community and the lawmaking power. Before entering upon this portion of their work, the commissioners desire to recall attention to a passage in their previous report in relation to the topics involved in it. When they approached the subject a year ago they excused themselves from entering upon it, because of "the brief time they have had to pursue their investigations, the immense and conflicting interests involved, the necessity of falling into the fewest possible errors, and the utter futility of any legislation, which partakes rather of the nature of force than of an educated and reflecting public opinion. * * *

* Abstract of the Report of the Massachussets Board of Railroad Commissioners.

Any solution of the questions arising out of the intricate relations of the community and the railroad corporations requires time and study, and a hasty or ill-considered solution is worse than none at all. The problem needs but to be stated, to have the difficulties surrounding it appreciated. * * * No system which could possibly be proposed at this time would be based upon a correct understanding of these complicated considerations, or could command any general respect or stand the test of criticism. Such a work must be the last result, rather than the beginning of the labors of a commission." The distrust here expressed as to the value of their own conclusions is by no means yet removed from the minds of the commissioners. They are fully conscious that 18 months is a period very insufficient in which to master so difficult a subject. The careful consideration they have given to it during the last year has tended to impress them with a consciousness rather of the difficulties which surround it, than with a confidence in their own abilities to deal with them. At the same time the desire on the part of the last Legislature that this question should be met was so manifest, and the popular feeling in regard to its rising with such rapidity, that the commissioners feel that they have no choice left to them in the matter. Even if this were not the case, the language of Chapter 54 of the Resolves of the last session can hardly be considered otherwise than imperative. It must be taken to cover the whole ground and to direct immediate inquiry to be made.

The commissioners propose, therefore, to take up this discussion in the present report at the point where they abandoned it in their last. The experience and observations of another year, and the results of the United States census, have fully confirmed them in the conclusions heretofore expressed. The degree to which the future of Massachussets is bound up in the successful prosecution of manufacturing industry, was elaborately discussed in their first report, and the fact requires no proof, that, next to popular thrift and intelligence, the development of this industry chiefly depends on the excellence and freedom of our arrangements for internal communication. Little need be said in this connection of what is known as the through railroad business of the community—that which originates perhaps thousands of miles beyond the limits of the State, and, in greatest part, involves connecting lines of road, nine-tenths of which, perhaps, are beyond the jurisdiction of Massachusetts. Interests, second in importance to none, depend upon the promptness, economy, and facility with which this business is conducted; but, in the first place, the legislation of no single commonwealth can affect it in a very great degree, and that of Massachusetts hardly at all; and, in the second place, in most respects it is fortunately in a very satisfactory condition. Sufficient evidence of this statement is found in the returns for 1869–70 of the produce movement, which were adduced a year ago, as indicating the degree of success with which the all-rail routes kept up the competition with the mixed routes between Boston and interior points. The through all-rail routes are gaining more and more on the mixed routes, and now practically control the market. This, as was shown in the previous report, indicates that the movement in question is made at very low rates. Most of this, as well as other through business, is now done by what are known as the despatch lines. These have already been referred to in another connection in this report; but, as illustrating the extent of the combinations and the very slight degree of influence to be exerted over them through State legislation, a few figures may not here be out of place.

The Boston & Albany road belongs to three of these combinations, known as the Red, the White, and the Blue lines. No reports of these organizations are published, but the first is composed of four companies, aggregating 2,422 miles of road; the second of nine companies, aggregating 3,434 miles; the third of twelve companies, aggregating 4,413 miles. The very smallest of these combinations, five years ago, in 1865–6, immediately after its organization, employed on an average nearly 700 cars, while the largest of them, in 1869, employed over 1,800. The importance of these lines to the internal economy of Massachusetts cannot well be overestimated, yet there are within this commonwealth but 210 miles of the Red line, or 8.70 per cent. of the whole; but the same number of the

White line, or 6.10 per cent. of the whole, and but 418 miles of the Blue line, or but 9.47 per cent. of the whole.

Next to the Boston & Albany, the Boston and Lowell is the Massachuselts corporation most actively concerned in the large railroad combinations. The position of, and the results accomplished by, this corporation are, the commissioners believe, without a parallel. Owning in all but 26 miles of road, operating altogether but 125 miles, and representing but $5,000,000 of capital, this apparently significant company, through the energy and ability of its management, has of late exercised a most perceptible influence on the whole railroad system of the country, including the largest and most powerful of its combinations. The corporation has two direct and close connections with the West, one by way of Ogdensburg and the Lakes, the other by way of Montreal, the Dominion, and Detroit. Through these it has, during the last year, kept up a direct competition with the more southern routes between Chicago and the East; and, in spite of the greater distance traversed, being equivalent of 15 per cent. of the whole, this competition has been so effective that it has kept the rates to and from Boston and the West always as favorable, and often more so, than those to and from New York. This combination mainly operates for through business through the "National Car Company," a Vermont corporation, which furnishes to the several roads 500 cars with adjustable axles. During the ten months ending October 1, 1870, 16,805 tons of outward and 13,800 tons of inward freight have been moved in these cars at rates sometimes as low as 6 mills, but generally varying at from 1 to 2 cents per mile; while to and from Ogdensburg large amounts have been moved at $2.50 per ton, or 6 mills per mile. Meanwhile this combination, so important an element in the prosperity of the commonwealth, though it controls 400 miles of road to Ogdensburg and 1,150 to Chicago; though it has more than 1,000 additional miles of road contributory to it or fed from it; though it employs some 6,000 freight cars in doing its work of transportation in New England, yet has only 68 miles of it within the jurisdiction or subject to the laws of Massachusetts; not one-twentieth part of the whole.

The policy of Massachusetts as regards these great combinations is, therefore, manifestly dictated by circumstances; it should be one of extreme caution; it should rather avoid the creation of obstacles than seek to impose regulations. In some respects such a condition of affairs may operate harshly, but this is an evil incident to our political system, under which the power to "regulate commerce between the States," is delegated to Congress. The commissioners, therefore, do not propose to dilate upon matters over which they can exercise little practical influence; they prefer at once to turn the discussion upon a class of interests of not less importance to the commonwealth, and over which they may hope to exercise a control both direct and immediate.

If the through or external railroad relations of the commonwealth are in a condition even more satisfactory than they were a year ago, the commissioners greatly regret to say that the same cannot be said of the internal system. A similar criticism was made in their first annual report. It was then intimated that a reform was necessary in the whole method of internal transportation; the tariffs of different roads were compared, and gross and inexplicable variations in them found to exist; the system of delivery was pronounced defective, and finally the corporations were called upon to themselves undertake the work of renovation, thus making unnecessary any attempt at governmental interference. At the close of another year, however, the commissioners are not aware of a single step taken or even in contemplation towards the end indicated by them. It is, of course, impossible to regard such a result as in any way satisfactory, and it only remains for this Board to sit down under a confessed inability to accomplish anything, or to have recourse to more definite language, and to suggest a more decisive line of action. Under these circumstances, and pursuing their investigations under the resolve of the last Legislature, the commissioners feel no disposition to shirk any responsibility or to avoid the issue presented.

The commissioners base their investigations and all their economical conclusions on this principle: All sums exacted from the community for transportation, whether of persons or of property, constitute an exaction in the nature of a tax,—just as much a tax as water rates, or the assess-

ments on property, or the tariff duties on imports. That it is wholly, or in part, a necessary tax—one which can at most only be reduced to a certain point, but never abolished—this in no degree affects the principle. It is still a tax, adding in itself nothing to the intrinsic character of property, nor affecting the condition of persons, but simply moving the one or the other from point to point. The reduction of this tax to the lowest possible amount paid for the greatest possible service rendered, always observing, of course, the precepts of good faith and the conditions of a sound railroad system—this must be the great object the commissioners retain always in view. Much is constantly heard of the importance of railroad charges as an element in the calculations of the Western agriculturist. Under this incessant discussion, and a spirited competition of trunk lines, the cost of transportation of Western produce to the seaboard, has now been reduced to a point hitherto regarded as chimerical. During the last summer 3 mills per ton per mile has been a rate not unknown. The commissioners have no criticism to make upon this.

Any arrangement which enables the farmer of the West to successfully compete with the producers of the Danube and Black Sea is a subject of national rejoicing. The commissioners desire none the less to express grave doubts whether the transportation tax weighs as heavily, after all, upon a farming and agricultural region as it does upon a manufacturing district as peculiarly located as Massachusetts. It here appears in every possible shape; it is encountered at every step. It may safely be asserted that there is no branch of Massachusetts industry which is not carried on against competitors more advantageously located. The State has very few natural advantages; but eveything with her depends on the intelligence of the people and the cost of transportation. The West in producing cereals has at least a soil of unsurpassed fertility; Pennsylvania in manufacturing iron has the ore and the coal in close proximity to the furnace; the English mill-owner has his power and his labor in cheap profusion. Almost every article, however, which enters into the industries of Massachusetts has to be brought within her limits from a distance. Her very water-powers are subject to inclement winters and dry summers, while she has to make her ingenuity supply a deficiency in labor. Her food is, then, brought from the Northwest; her wool and her leather from South America, Texas, California, and the Central States; her cotton from the South; her ores from the Adirondacks; her coal from Pennsylvania; her copper from Superior, and the list would admit of indefinite extension. Massachussetts is thus merely an artificial point of meeting for all kinds and descriptions of raw material, which is here worked up and then sent abroad again to find a consumer. At every point, coming and going and in process of manufacture, it has to be transported, and it has to bear all costs of transportation in competition with articles of the same description produced elsewhere and by others. Every reduction of the transportation tax, acts, then, as a direct encouragement to the industry of Massachusetts, just as much so as if it were a bounty or bonus,—it is just so much weight taken off in the race of competition.*

As regards the transportation tax, it is almost impossible to derive any results of value from a comparison of statistics. This tax has one peculiarity in common with the tariff duties on imports—the lower it is fixed, within certain limits, the larger in its aggregate it becomes. A large *per capita*, therefore, by no means indicates an oppressive scale of charges, but rather the contrary. Industry pays a large tax because the tax is fixed at a point which enables industry to pay it. For instance, the average contribution of each human being in the United States to the earnings of the railroad system is estimated by the best authority at about $10 per annum.* Manufacturing communities always make much more use of their railroads than any other. Yet while the *per capita* in Massachusetts rises only to $13.81 per annum, that in Pennsylvania rises to over $20. This apparently is largely due to the fact that a single corporation in Pennsylvania, moving alone five-sixths as large tonnage as all the roads in Massachusetts combined, and

* The table in the report, which is omitted here, indicates that the existing productions estimated at $700,000,000 annually pays, on account of municipal taxation and transportation, over $40,000,000 per annum.

* Manual of Railroads of the United States, 1870. H. V. Poor. p. xxxvi.

returning nearly as large an income,* makes this great movement at a charge per ton per mile of a little less than one-third of the usual charge on local movement in this State. The charges on the road referred to and on eight Massachusetts roads are set forth in the accompanying table.

Average Rate per Ton per Mile in cents on Freight Moved in 1869.

	Local Freight.	Through Freight.
Boston, Clinton, and Fitchburg	6.15	5.21
Boston and Lowell	7.15	2.98
Boston and Maine	5.04	3 43
Boston and Providence	3.42	4 54
Cape Cod	3.53	4 85
Cheshire	7.32	2 86
Eastern	6.35	2 56
Fitchburg	7.46	2.72
Norwich and Worcester	4 40	4.00
Pennsylvania	1.72	1.72

The Boston & Albany road should be included in the table, but unfortunately this company does not discriminate in its returns between earnings from through and local freights. Its average charge per ton per mile on its entire freight movement in 1869 was 2.43, or 41 per cent. above that on the Pennsylvania road. No reliable conclusions, however, can safely be drawn from such a comparison; that here drawn by the commissioners is probably correct, but, while one State has a through produce or transit business, or a coal traffic, or a large manufacturing population, which another has not, it is impossible to argue certainly from the one to the other.

The case stated, however, fully serves to illustrate the distinction between the municipal and the transportation tax which the commissioners desire to point out. The larger the aggregate of the municipal tax, the heavier the burden imposed by it on the production of the State; while, on the contrary, the higher the total of the transportation tax rises, the greater is the volume of business and the lower are the tariff rates probably indicated. The municipal *per capita* and the transportation *per capita* in Massachusetts are each about $13.80 per annum; the first is 30 per cent. higher than the *per capita* of New York, and 64 per cent. higher than that of Ohio, while, as regards cities, the *per capita* tax of Boston is 35 per cent. higher than that of New York, while that of Philadelphia is but 40 per cent. of that of Boston.

A sufficient reference has already been made to the *per capita* transportation tax in this State; so far as any deductions can safely be drawn in regard to it, it would seem to be nearer the average of the whole country than should be the case in so busy and thriving a community. In any event, it is safe to say that, taking the two together, a very heavy and oppressive burden is imposed on the annual production of the State. To reduce it, is simply to give the Massachusetts manufacturer an equal chance with others in the common market. Meanwhile, so far as the ultimate effect is concerned, in the impetus given to production, a reduction in the municipal tax or a reduction in the transportation rates operates in exactly the same way. A reduction on an average of 20 per cent. in existing railroad tariffs throughout Massachusetts would probably, though it might decrease net earnings, double gross earnings, which are the aggregate tax, and have much the same effect on the prosperity of the commonwealth as doing away with the whole State tax.

With the municipal tax this Board has no concern. The figures concerning it are adduced here simply for purposes of illustration. The discussion of railway charges is of at least as much consequence industrially to a people as the whole ordinary question of taxation; but, in discussing it, the object the community should ever keep in view is, not to reduce the gross amount it pays, but so to regulate and dispose of the burden as to enable it continually to pay more. The commissioners desire, therefore, to remove in the outset any false, though perhaps popular impressions which may exist in regard to what they have here designated as the transportation tax. They are very far

* The following are the exact figures in two cases referred to:—

1869.	Tons Carried.	Gross Earnings.
Pennsylvania Railroad	5,402,991	$17,250,812 00
Massachusetts Railroads (total)	7,378,083	24,539,722 00

Deduct from the totals of the Massachusetts system 22 per cent., as representing the amount properly to be credited to portions of the roads lying in other States, the entire railroad system of Massachusetts proper will be found to return a tonnage movement of 351,914 tons, and a gross earning of $1,380,172 more than the Pennsylvania Railroad.

from implying or believing that it has been exacted for insufficient services rendered, or that it ought to be or ever can be abolished. On the contrary, it is a payment which has been cheerfully made in compensation for services of inestimable value. Unless, however, both the nature and the magnitude of the burden are clearly understood, it will be impossible to appreciate the prodigious relief and impetus which any sensible reduction of rates must afford to Massachusetts.

Before entering into the discussion as to what, if any, reduction is possible and how it could best be effected, it may be well to examine into what has been already done by the railroads looking in this direction. In order to do this the commissioners have gone back over a period of ten years.

This comparison establishes the fact that, so far from any reduction having been made in their local fares and freights by the railroads of this commonwealth during the last ten years, a directly opposite course has been pursued. The tendency has been towards an increase rather than a decrease, and the rates are to-day, as a whole, higher than they were in 1860.

As a contrast to this policy, and to lend force to the criticisms they propose to make upon it, the commissioners wish here to call attention to the results of a different course pursued elsewhere during almost the same period. The Belgian railroad system now aggregates 1,703 miles in a territory of 11,403 square miles of area, being a mile of railroad to each 2,900 souls in its population and to each 6.69 square miles of territory. Massachusetts has 1,491 miles in a territory of 7,800 square miles of area, being a mile of railroad to each 971 souls in its population, and to each 5.23 square miles of territory. Both are manufacturing communities, and, though the population of Massachusetts is less dense than that of Belgium, it is far more disposed to move from place to place. So much is this the case that, in spite of the reduced rates in use in Belgium, and the more than twofold population there, in 1868 its railway system carried only 23,607 passengers for each mile of road, as against 19,700 per mile for the same year on the Massachusetts roads. In regard to freight, however, the case is different. The Belgian roads in 1866 transported 12,211 tons per mile of road, while the Massachusetts roads transported only 4,948. There are, therefore, no fundamental differences as regards physical or economical or industrial conditions which should cause the experience of the one community to be wholly inapplicable to the other.

In 1856, in spite of a considerable increase in the miles of railroads worked, the freight movement of the Belgian roads was found to have seriously decreased. Instead of making good the deficiency in receipts by increased rates on existing business, the administration met the emergency by accepting all traffic that offered at greatly reduced special rates. This policy succeeded so well that in 1861 the principle was adopted, as regards minerals and raw materials, of a regular low scale of charges, with a reduction according to distance. This resulted in the following year in an increase of 72 per cent. in the tonnage of this class of goods. In 1862 the principle was extended to goods of the next class with similar results. In 1864 freights were re-classified, and the new principle applied to all except the first class, or small parcels, which in this country are known as express matter.* The result was summed up by the Minister of Public Works as follows: "In eight years, between 1856–64, the charges on goods have been lowered, on an average, by 28 per cent.; the public have sent 2,706,000 tons more goods, while they have actually saved more than $4,000,000 on the cost of carriage, and the public

*The Belgian tariff is quite complicated, and it is not deemed expedient to endeavor to analyze it here. Meanwhile the following comparison of charges made on English and Massachusetts roads with what they would be under the Belgian tariff, will perfectly illustrate the practical working of the system. The English and American charges are those in use on existing corporations, and between specified termini selected at hap-hazard. The Belgian charges are computed.

Articles Transported —Per Ton.	Distance in Miles.	Rate.		
		English	Massachusetts.	Belgian.
Butter	32	$2 40	$2 00	$1 16
Lumber, (1st road)	35	2 16	2 60	82
" (2d road)	39	2 40	2 20	88
" (3d road)	65	3 00	2 80	1 20
Sugar	100	3 90	5 00	2 90
Groceries	116	5 60	5 80	3 30
Hardware	116	6 60	5 80	3 24
Pig Iron	126	3 60	3 80	1 44
Bar Iron	130	4 60	4 60	2 16
Earthenware	150	7 20	5 80	2 16

treasury has earned an increased net profit of $1,150,000." A further reduction, made subsequently to this statement, in 1864, exceeded even these results, and under it the tonnage rose from 4,479,000 tons, in 1863, to 6,533,000 in 1864.

In 1865, the Government, encouraged by these results, turned its attention to fares, now applying to them the principles before applied to freights. A general scale was adopted, in which the charge per mile was diminished in proportion to the length of the journey over 22 miles. For distances less than 22 miles the old rates were retained, varying between 1.2 and 2.5 cents per mile, according to the class of carriage. Above the 22 miles the rates rapidly decreased until the fares for distances over 155 miles were as low as 1 cent per mile for first class, and 7 mills per mile for second class tickets. Under this system the fare from Boston to Albany, for instance, would be respectively $2, $1.40, and $1, according as it was paid for a first, second, or third class ticket. The effect of this change was a singular and very striking illustration of the immediate influence of any reduction of rates on the volume of travel. The traffic within distances of 22 miles, on which no reduction was made, scarcely increased at all. Between 22 and 46 miles, on which distances the reduction was small, it increased only 20 per cent., while on distances over 46 miles, on which a heavy reduction was made, it nearly doubled.

The commissioners regret very much that the more recent official documents relating to these experiments are not now within their reach. They cannot be found in any of our public libraries, and the commissioners have not yet succeeded in procuring them from abroad. Their knowledge is, therefore, derived at present from second sources, and any further statement of results would not be free from doubt.

If such, however, have been the results of a bold system of reduction elsewhere, the question naturally suggests itself: Are those tariffs which have so long existed on our Massachusetts roads the lowest at which they could be operated at a profit, no matter how much their volume of business was increased? If they are, how does it happen that the conditions affecting transportation are so different here from those found to exist in other, and not dissimilar communities? If these questions were put to the railroad officials, they would probably answer by referring to their returns; they would show that, under their present tariffs, the roads could not earn the allotted 10 per cent. dividends, and were often unable to supply the means necessary to meet the requirements of an increasing business.

Such an answer could not be considered satisfactory. A similar one was persistently advanced against all reduction in the case of high postage. It wholly ignores the recent experience of the corporations themselves as regards certain descriptions of through business, in which low rates have so stimulated transportation that the railroad managers themselves are unable to say where profit ceases and loss begins. That certain companies have been losers at the rates under which they have carried cannot well be denied; but that any company has lost by carrying through freights at 25 per cent. of the average charge for local freights in Massachusetts is extremely doubtful. Under these circumstances the commissioners wish very clearly to set forth their views as to the policy which the corporations should adopt as regards this important question; that policy should be a tentative, but a persistent one,—a continual effort to see when and how and where any portion of the burden now pressing on industry could be so removed or so shifted as to enable production to expand, thus replacing in one direction what was conceded to it in another. The commissioners call for no sacrifice of dividends; they do ask for a constant exercise of ingenuity and for a sacrifice of ease. The community has a right to demand increased facilities from its corporation, even though it may not promise any increase of net earnings in return, provided only such new facilities do not involve an actual and decided loss.

The commissioners believe they speak within safe bounds when they express the opinion that an average immediate reduction of 10 per cent., with an ultimate and not very remote reduction of 30 per cent., could be made throughout the railroad tariffs of the State without permanently reducing net earnings in any appreciable degree. The increased business would, within a very limited period, more than make good the reduction, provided of

course that such reduction was judiciously and skilfully made. Not a few railroad managers, however, frankly say that they do not care for this or that business; that it is not remunerative ; that they do not see the object of a policy which could only compel the corporation to do twice as much work with no increase, and perhaps even a perceptible diminution of net income. From the employé point of view this argument is certainly entitled to great weight. The commissioners, however, while they do not propose in any way or at any time to suggest interference with the reasonable, and even liberal net earnings of the companies,—while they are confident that no thought of so doing exists either in the Legislature or the community at large, yet, at the same time, they are not disposed to attach weight to considerations such as those referred to. Very valuable charters, and privileges practically exclusive, have been conferred on these corporations upon one single consideration,—that, as trustees, they should watch over the interests confided to them, and that, as public servants, they should zealously perform all duties within the sphere of their functions. The dividends were to be a compensation for the performance of these duties. The community has certainly fulfilled its part of the contract, both in the letter and in the spirit, but the tables already presented would seem to indicate that the corporations have taken a more literal view of their responsibilities. They have, it may be inferred, been disposed, so to speak, to leave well enough alone, ignoring the fact that nothing was to be considered "well enough" which admitted of improvement.

The commissioners cannot ask a corporation to carry on any branch of transportation at a direct and acknowledged loss. To do so would be to place themselves in an apparently untenable position. Yet they do not hesitate directly to assert, what they intimated a year ago, that there are many articles of raw material which a sound railroad policy should induce the Massachusetts corporations to transport without any profit, if not even at a direct loss. A case exactly in point is presented in the movement of produce. Prominent railroad officials have assured members of this Board that, though of late often carrying food at a loss,—"failing to get back a new dollar for an old one,"—they had yet never done any business at once so rich in results both for their roads and the community. They had built up a local trade,—made living cheap along their routes,—and, from the regular and multifarious demands of those thus made dependent upon them, they had replaced many fold their loss on the carriage of articles of prime necessity. If this has proved true of food, why should it not also prove true as regards coal and ores, and raw material generally? Indeed the commissioners do not hesitate to express it as their opinion, that a large view of their own interests should induce every railroad corporation in the State to offer at once a standing reduction of at least 30 per cent. from regular tariff rates on the carriage of all articles, certified as raw material for manufacturing purposes, to be used at points on the line of their roads. This course would build up a busy community wholly dependent on any corporation which fostered it. As already stated, the average payment to the railroads by each human being in Massachusetts is at least $13.81 per annum. Where, then, a railroad builds up its local industry, it simply increases the number of those who contribute to its treasury $13.81 each year. The railroad then has a more direct interest in manufacturing development than any other portion of the community. Why, with these facts before them, the corporations insist, as they do, upon exacting a direct profit from every form of carriage of raw material, the commissioners are wholly at a loss to understand. They would still get a profit if they carried it for nothing. The commissioners can only say that, in their opinion, the policy generally pursued in this respect is singularly shortsighted and shallow ; they cannot, however, of course, suggest any legislation calculated to compel corporations to benefit themselves by operating at a loss.

If the conclusions to which the commissioners have come are correct, it manifestly becomes of great moment to know what prospect there is of their practical adoption by the railroad companies. Nothing has come to the knowledge of this Board which encourages its members to hope that the recommendations now made by them will be followed by any more practical results than those made a year

ago. The corporations are naturally wedded to their existing modes of doing business, and look with justifiable distrust on measures of reform emanating from without. The commissioners on the other hand can give them no absolute assurance that the changes they suggest may not result in disaster. Under these circumstances it only remains to devise some method, other than simple recommendation, of effecting the desired result. The commissioners desire, therefore, at this time, to recommend a more definite line of public action to the Legislature, and one which can be adapted to any emergency. In doing this, however, they do not wish to create the impression that any immediate exigency exists—that it is necessary, or even desirable for the community to incur any unusual risk. On the contrary, the present is a time peculiarly appropriate in which to originate a policy, for it can now be done under conditions involving no haste and free from all excitement. The commonwealth is increasing in wealth and population—industry is remunerative—the workshops are busy. If this condition of affairs is to be permanent, however, it is necessary to husband every resource and to remove every unnecessary burden. The present, therefore, being a period of preparation, the commissioners accept it as one very favorable in which to bring forward this delicate question. Watching the development of public experiments, the corporations can enjoy an ample leisure in which to make up their minds as to the course they prefer to pursue, while the commonwealth, cautiously advancing, need commit itself to no heavy expenditure or untried theory.

There are then two questions on which this Board now feels called upon to express opinions:—1st. How can the existing corporations most effectually be brought into a close sympathy with the wants of the community and the popular expectations?—and, 2d. In case of the failure of all attempts to create this close sympathy, how can the community be most readily prepared to substitute a new and more satisfactory system of management for that now existing?

These questions were somewhat considered during the session of the last Legislature. A law was passed declaratory of the general right of the Legislature to regulate at its discretion all tariffs of fares and freights on the several railroads of the commonwealth, without regard to the amount of net earnings. The commissioners are unable to see how any satisfactory results can be arrived at through action under this law. The grounds on which they base this impression can be stated in very few words. All legislation in the direction indicated must be either general or special—general as applying to all the railroads of the commonwealth, or special as applying to some individual one of them. No general law of this nature has yet been framed adequate to meet the wants of the case, though attempts at it have frequently been made; nor, indeed, do the commissioners now see how such a law could be framed. Not that it is here meant to imply that the regulation of railroads by law is impracticable, but the doubt is confined to their regulation in this particular way. Other methods have been, and hereafter will be suggested, and their practical merits can only be ascertained after trial; this method has, however, repeatedly been tried and with a uniform result. The cause of failure in this case is indeed most apparent. A general law regulating fares and freights, which would very slightly touch one road, would inevitably ruin another; a tariff which would apply to one class of articles, would be simply ridiculous when applied to another. The law found generally on the statute books provides a *maximum* per mile for each passenger and for each ton of freight. A law on this principle framed to meet the case of the Boston & Albany road, by materially reducing its present rates, whatever result it might produce on that company, would speedily send the Housatonic road into insolvency; a law which allowed the Housatonic to earn a dividend would have no application to the Boston & Albany. So of descriptions of freight; a rate per ton per mile applicable to coal or pig iron, would produce results eminently unsatisfactory to the corporations if applied to feathers, wicker-work, wooden-ware or household furniture. It is, however, useless to discuss this question; a general law which shall meet the circumstances of all the separate roads and provide for all classes of freights, degrees of speed, and arrangements for comfort, is a practical impossibility. It may, however, be

urged that the law of 1870, was intended to pave a way for special legislation to meet individual cases. This is very probably the case; at the same time, should the Legislature undertake to follow out the plan indicated, and to specifically regulate the tariffs of each railroad of the commonwealth, according to its particular circumstances, or the needs of its surrounding community, it will launch itself into an ocean of special legislation such as has never yet been attempted, and no large legislative body could successfully attend to. Should it delegate a power in this regard to the present or any other board of commissioners, it would simply destroy it by so doing. A responsibility would be imposed unsustained by any executive power. An authority to regulate fares and freights over roads owned, controlled, and operated by others, would place those in whom such authority was reposed in an entirely false and impossible position. Those managing the roads could produce what results they saw fit; they could easily demonstrate, by apparent practical workings, the absurdity of anything which was distasteful to them. They could reduce to real failures the most correctly reasoned theories. It is useless for the Legislature to look for satisfactory results from the labors of any board which can only work through reluctant agents, and the position of one who can direct but cannot execute is in the last degree unfortunate. It resembles nothing so much as that of a military commander, all of whose subordinates feel a direct and lively interest in his failure.

For these reasons, the commissioners do not believe that the desired relief lies in the direction towards which the legislation of last winter pointed. They believe it does lie in a directly opposite direction. The course they would recommend is the following: let the State adopt its own plan of railroad management, wholly independent of the private railroad corporations; how this plan should, in the opinion of the commissioners, be developed, will be set forth in the subsequent part of this report; having done this in such a manner as to commit itself to the least possible expense consistent with a perfect trial of a great experiment, recognizing it simply as a tentative effort, let the State then give the existing corporations distinctly to understand that the continuance of their corporate existence depends wholly on (1) the results of the experiment in operation; (2) on their own success in the process of competitive development side by side with it. All restraints should then be removed from the private corporations; they should be allowed, within the limits of the law, to freely follow their own devices; the two systems would thus be compelled to work their way out in visible and perfect contrast, and that which, at the expiration of a reasonable term of years, should prove itself to be best, would undoubtedly be adopted with general acquiescence. The corporations, however, should not hereafter have it to say that they were tramelled or tied down during the period of trial; the principle of private corporate management should have full play, while it distinctly understands that it is on probation.

Whether the corporations should hereafter meet more fully the expectations of the community, or should fail to do so, the commissioners would recommend that the State should be prepared to take its own course. The commissioners do not propose in this connection to discuss the question of State ownership of railroads. There are arguments, based both on theory and experience, in favor of it and opposed to it. In this country it has not hitherto been attempted with success; but it is not clear that failure did not arise from the effort both to construct railroads and to originate a system of operating them; nor, indeed, was failure confined to public enterprises, as it is a matter of notoriety that all the early railroad undertakings in private hands passed through long periods of extreme depression and financial tribulation. There are also very grave political considerations involved. The principle upon which our Government is founded—that of least possible governmental interference and largest possible individual development—has a strong hold on the popular mind. The public opinion of the commonwealth unquestionably accepts with great reluctance any measure calculated to bring industrial enterprises within the influence of politics. At the same time, a strong and growing popular conviction cannot be ignored, that railroads and internal communication constitute an excep-

tion to this general rule. The success which has attended an opposite policy in Belgium, and the experiments now in progress in Great Britain, have by no means escaped notice. The political considerations involved do not however fall within the province of this board; it is for the commissioners simply to recommend that course which is, in their opinion, best calculated to certainly and safely reduce the transportation tax; and it is for the people and their direct representatives to decide whether the advantages likely to flow from that policy are or are not counterbalanced by the dangers to our political system involved in it. The problem before the commissioners is a purely material one, and it is for another tribunal to weigh ulterior and political considerations. The commissioners do not therefore propose to argue these questions or to commit themselves to any opinions in regard to them. Neither, on the other hand, are they disposed to recommend anything rash or sweeping; but, while they do not wish to destroy the old until the new is established, the new can only be confidently pronounced either a success or a failure after a fair course of experiment. There is nothing to prevent private ownership and State ownership of railroads from existing at the same time in the same community. They have always existed, and still do so exist in Belgium. According to the statement of M. Fassiaux, at the time Belgian Director-General of Posts, Railways, and Telegraphs, made to the British Royal Commission on Railways of 1868, there were on January 1, 1864, 1,247 miles of railway in Belgium. Of this amount, 347 miles had been constructed and were worked by the State, belonging to it without reserve. The State derived the profit or suffered the loss, as the case might be, resulting from the working. In addition to this, 117 miles, constructed by private companies and worked by the State, were likewise the property of the State, though a proportion of receipts was paid over to the companies who constructed the roads, as the remuneration for work done. The remaining 780 miles were both constructed and worked by private companies, free from public control. The practical operation of the mixed system of ownership thus existing in Belgium might reasonably be expected to somewhat reproduce itself in Massachusetts. Of it M. Fassiaux said in the examination already referred to, "the State railways thus, through a mixed system of ownership, find themselves placed in constant comparison with the railways worked by private companies; on the one hand stimulating them to general improvements, and on the other hand acting as a sort of check against any attempt to realize extravagant profits at the cost of the public." These are the identical effects which the commissioners desire to see produced in Massachusetts. Instead, however, of expressing them as something which might be anticipated, they are here quoted as the actual conclusions of a long experience.

Actuated by these considerations, the commissioners would therefore suggest that the time has come for a practical attempt at the ownership of railroads by the State, and their management with a direct view to the interests of the public. They would therefore recommend that the Legislature, under its reserved power, take measures to immediately assume possession of some line of railroad within the limits of the commonwealth. The next question is, Where, and under what circumstances, can the experiment most advantageously be tried? Which of its roads can the State most advantageously assume? Numerous considerations would tend to influence a recommendation on this point. It is highly desirable that the road upon which this delicate experiment is to be tried should be wholly within the jurisdiction of Massachusetts; it would not be wise to imperil such a movement through the possible jealousy of one State at the ownership of a railroad within its borders by another State. Here in fact lies the great difficulty in the way of State ownership — a difficulty which no one yet has endeavored theoretically to meet. Massachusetts would certainly be very unwilling to see the State of New York assume possession of the Boston & Albany under some clause in the West Stockbridge & Albany charter, and proceed to manage that road "by the people of New York for the people of New York;" and so Connecticut and New Hampshire might not impossibly entertain a similar jealousy as regards roads partly within their limits.

Whether this should prove to be the case or not, however, it is very desirable that so serious and wholly unnecessary a risk should not endanger a mere preliminary experiment. In that experiment, at least, while there are railroads wholly within the limits of the commonwealth, there need be no question of jurisdiction involved. The next consideration is one of expense. It is not, in the opinion of the board, advisable for the commonwealth to involve itself too deeply at once in a novel experiment. There are in the State several roads of limited size and cost which would include every desired condition, and the possession of which could not entail any very serious loss or inconvenience, even in case of failure. In case of success, however, it is very desirable that the experiment should admit of a natural and indefinite expansion in the directions in which it was commenced—an expansion in the nature of a natural growth or development.

All of these conditions are perfectly supplied in the case of only one of the railroads of the commonwealth—that between Boston and Fitchburg. This road lies wholly within our jurisdiction; it could be assumed by the State for a moderate sum; in case of failure it could be disposed of without serious loss or public inconvenience; and, finally, in case the experiment resulted in success this route admits of indefinite expansion. In the last respect there is a peculiar propriety in selecting this road as the one on which to try the proposed experiment. The Hoosac Tunnel it is now confidently stated will be completed before the year 1874. It has been constructed solely by the public money, and it would be eminently fitting that, when completed, it should be managed solely in the public interests. By January, 1874, the experiment of State ownership and of public management would be so far advanced that a judgment could be formed as to the expediency of extending it. Were that judgment favorable, the rest of the line to Troy could then be assumed, and any question of State jurisdiction would thus be deferred until the preliminary experiment was an approved success, and then it must necessarily present itself. Were the results still encouraging, and were this difficulty overcome, the State road, commencing with the present 51 miles of the Fitchburg corporation, developing without undue haste and with no unnecessary assumption of risk or disregard of delicate interests, would in time place Massachusetts in direct communication with the Canadas, the West, and the Middle States; through the northern railroad system and Lake Champlain it would receive the breadstuffs of the wheat-growing region and the ores of the Adirondack; through the channels of the Delaware & Hudson Canal Company, it would communicate directly, both by water and rail, with the coal-fields of Pennsylvania. No other route in Massachusetts so properly and undeniably belongs to the community—for this route the tunnel will create, and the commonwealth made the tunnel; in assuming it she would assume but her own. The commanding position of the line in the future is now scarcely appreciated; towards the north and northwest it has all the advantages of the Boston & Lowell road; towards the west and southwest all those of the Boston & Albany; situated between the two, it could bring to bear a direct competition on each, and thus at once practically regulate the whole railroad system of the commonwealth.

The commissioners would, therefore, recommend the Legislature to take immediate steps towards assuming possession of the Fitchburg Railroad. While making this recommendation, they do not propose to enter into particulars as to the steps involved in carrying it out, or to report any draught of a bill. These, however, as well as the main subject, have been matters of anxious and careful consideration with them. Should the Legislature or the Committee on Railways be disposed to proceed in the path indicated, the services of the commissioners will be at their command. A very few days, it is believed, will suffice to mature all necessary legislation. Until, however, there is some indication that this is desired, and until the general subject can receive the consideration of the committee, the commissioners have not felt disposed to encumber this report with details. They propose only to offer a general sketch of a policy.

On two points, however, they desire at the start to place their opinions on record, and to remove all possibility of misconstruction.

1. As regards the rights of the present owners of the Fitchburg Railroad Company.

2. As regards the question of State management.

The commissioners cannot entertain a doubt that, in so far as the rights of private property are concerned, they will be guarded with great jealousy in any legislative action which may be had. Not only should the letter of the law be conceded, but in all doubtful cases the commonwealth should decide against itself. It should be remembered that the stock certificates of these railroads are not only the title-deeds of property, but the patents of public benefactors. They represent private means supplied to carry out a great public enterprise surrounded in its early days by doubt and risk. It may now be advisable to resume the ownership of the enterprise, but it is especially fitting that every reasonable claim of the present owners should be met in a spirit both of justice and liberality.

The Fitchburg Railroad Company now owns, in main and branch lines, 93.23 miles of track, with 50 miles of double track and 26 miles of siding, being in all, as near as may be, 169 miles of single track. This property is represented by $3,640,000 in stock, the corporation being free from all indebtedness and having a balance of $501,230 in its treasury. Computed in the usual method, the road would be said to stand at an average cost of $38,000 per mile, as represented by all outstanding evidences of property.

There are three methods by which the State can take possession of the franchise and possessions of this company, viz.:

First. Under section 84 of chapter 39 of the Revised Statutes, which provides that "the commonwealth may, at any time during the continuance of the charter of any railroad corporation, after the expiration of 20 years from the opening of said railroad for use, purchase of the corporation the said railroad and all the franchise, rights and privileges of the corporation, by paying them therefor, such sum as will reimburse them the amount of the capital paid in, with a net profit thereon of 10 per cent. per annum, from the time of payment thereof by the stockholders to the time of such purchase."

Second. Under the declaratory Act of the last Legislature which provides that "the commonwealth may at any time take and possess the road, franchise, and other property of any railroad corporation after giving one year's notice in writing to such railroad corporation, and paying therefor such compensation as may be awarded by 3 commissioners, who shall be appointed by the Supreme Judicial Court, and shall be duly sworn to appraise the same justly and fairly. Said commissioners shall estimate and determine all damages sustained by any such railroad corporation by such taking of the road, franchise, and other property thereof, and any such corporation aggrieved by the determination of said commissioners, may have its damages assessed by a jury of the Superior Court in the county of Suffolk in the same manner as is provided by law with respect to damages sustained by reason of the laying out of ways in the city of Boston."

Third. In the usual business manner pursued by individuals or corporations in similar cases, through negotiation and purchase; as has been done in the case of the telegraph system by the Parliament of Great Britain, and is proposed as regards the railroads of Ireland.

If the commonwealth took possession under the method first stated it would be necessary to compute the excess of interest at 10 per cent. over the dividends actually paid by the corporation since it was organized. The commissioners have not verified the figures contained in the report of the commission on cheap transportation to the Legislature of 1870, but, assuming them to be correct, the amount of dividends now in arrear appears to be between 92–3 per cent. of the capital, amounting to a total $3,357,000, aggregating, together with the stock capital, almost exactly $7,000,000; or, otherwise stated, the road, if purchased in this way, would cost the commonwealth in the immediate neighborhood of $75,000 per mile, or $192 per share. As the stock now commands a market price of $136–7, any arrangement of this nature would certainly constitute no hardship on the shareholders.

In this connection it is of interest to see what, on the same basis of computation, would be the cost to the commonwealth of its other leading railroads. According to the tables already referred to, the cost of the Boston & Maine would

be $146 per share, or in round numbers $80,000 per mile; that of the Eastern $177 per share, besides a bonded debt of $3,037,400, amounting to about $104,000 per mile; that of the Boston & Lowell, $180 per share, besides a bonded debt of nearly $255,000, amounting to about $113,000 per mile; that of the Boston & Providence, $185 per share, amounting to about $105,000 per mile; that of the Old Colony, $167 per share, besides a funded debt of $2,986,600, amounting to $79,000 per mile. Owing to the consolidation of the Boston & Worcester and the Western railroads, and the complicated questions involved, it is very difficult to estimate the excess of interest over dividends due on the stock of the Boston & Albany. It is, however, not unsafe to say that, at the time of consolidation, a deficiency of $2,415,000 existed as regards the Boston & Worcester, and $1,400,000 as regards the Western, aggregating $3,815,000, without including the stock dividend of 1868. The present capital and indebtedness of the consolidated road is not less than $21,000,000, making an aggregate in the neighborhood of $25,000,000 on 250 miles of road, or $100,000 per mile. Even, therefore, through the extravagant method provided in the original Act, the Fitchburg road would seem to be in its cost per mile the cheapest in the State for the commonwealth to assume.

The commissioners are unwilling to commit themselves to any estimate as to the value of this road, should the commonwealth desire to possess itself of it in the method prescribed in the Act of 1870. It is wholly impossible to say what rule or measure of damages the commission or court would lay down in the premises. If the actual present value of the property, or the cost to replace it as it stands, was the measure, it is impossible, without long examination, to say what that would amount to. It would, undoubtedly, largely exceed the average of $38,000 per mile, at which their road nominally stands on the books of the company. It would, probably, considerably exceed the present market value of the stock, but the commissioners can form no reliable estimate whether it would exceed or fall short of the $75,000 per mile arrived at through the computations heretofore made.

The other, and in the opinion of the commissioners, the most judicious method to pursue, is that through negotiation and purchase, reserving the statute methods as a final resort. This method avoids all litigation and hard feeling, and is the more simple and expeditious, as well as much the most economical. The stock of this corporation has of late received 8 per cent. dividends, and now sells in the market for about $136 per share. Under the law of the commonwealth the dividends are practically limited to 10 per cent. per annum. During the last ten years the company has averaged 7.4 per cent. annual dividends, and has never risen above 9 per cent. During the last year it has barely earned its usual dividend, its gross receipts falling off about $85,000, and its net earnings nearly $40,000, their estimated amount ($303,000) being equal to a dividend of 8.32 per cent.* In view of this decrease apparently the directors of the road have fallen into, what the commissioners cannot but consider, the fatally shortsighted policy of raising the rates of their local freight tariff. This mistake is rather likely to increase than decrease the falling off, and the company can hardly look forward with any confidence to being for an indefinite time to come more than an 8 per cent. road. Assuming this as a basis of negotiation, it is difficult to see on what ground the corporation could refuse an offer from the State, of guaranteed 6 per cent. bonds at par in exchange for the stock of the road at a premium of $50 per share. Every holder of such bonds would, in place of 8 per cent. dividends, subject to all sorts of contingencies, and with 10 per cent. in remote possibility, annually receive from interest and after exchange, 9 per cent. guaranteed, or in cash, $14 per share above the selling market price. Purchased on this estimate, the road would come to the commonwealth at an average cost per mile of $50,000, and the commissioners think it safe to say that such a purchase would be one fair and advantageous to both parties. The question is, indeed, not without difficulties, but difficulties of the same nature surrounded the purchase by Government of telegraphs in England and of railways in Ireland, and were not found insuperable. Until, however, they could know directly and dis-

* As the returns for 1870 include but ten months, exact amounts cannot be given. In the above statement the returns of ten months are averaged over the entire year.

tinctly what are the wishes and policy of the Legislature on this subject, the commissioners have not, of course, felt at liberty to make any overtures to the parties in interest.

Upon the second point, that of State management, the commissioners desire to express their hope that State ownership will not be found to necessarily imply State management. Indeed, in their opinion, the whole result of this important experiment turns on the success with which the question of management can be kept out of politics—can be held distinct from all party machinery. In this respect many excellent provisions are contained in the bills reported to the last Legislature by the commission on cheap transportation. The end in view is, to provide a machinery through which the direction of the road shall be confided to trustees, with duties in the nature of those ordinarily pertaining to supervisors of highways. Neither the State nor the trustees undertake personally to manage the road, but they simply produce a paid manager, who, only, is directly responsible, and who takes charge of the road under the advisory supervision of the State trustees. One improvement in the machinery proposed, the commissioners wish decidedly to recommend. Recent scandalous proceedings in other States have illustrated the necessity of introducing some form of minority representation into corporate elections. In the case of the Erie Railway, and in that of the Boston, Hartford & Erie, many of the largest as well as the most respectable of the stockholders of each company are absolutely deprived of all participation in the management of their property, and even of the power to protect it. However the systems of minority representation hitherto suggested may apply in practice to complicated popular elections, no question can exist that they are perfectly adapted to corporate elections, and would furnish a great safeguard against evils now notorious. If the trustees for the proposed road are, therefore, to be elected by the Legislature and from the community at large, it would be well to adopt some system which will enable any considerable class in the community to obtain a representation among them, in order to introduce into the Board that activity of thought and management which results from the mere discussion of theories which may yet be rejected; and, finally, this would afford every human precaution against those dangers which in this country so easily beset all public industrial enterprises.

Before bringing this long report to a close, it only remains for the commissioners, in a few words, to restate the policy they wish to see initiated. They propose that the two systems of operating railroads, that through a public and that through a private management, should be placed side by side, each under the auspices most favorable to development, and subject to no laws but those of Massachusetts. Both systems will distinctly understand that they are on trial; the private corporations will have a reasonable time afforded them in which to justify the existing management; but, if their results through the coming years are less advantageous to the public than those produced through State control, they must be prepared to surrender their trusts into the hands which conferred them. The managers of these corporations cannot complain that the trial is not a fair one, upon the ground that the State road will be operated regardless of profit, while they will be expected to keep up their dividends. The State road must, under public management, pay the interest on its whole purchase cost, being the equivalent of at least nine per cent. dividends on its present outstanding stock. If, in addition to this, it fails to keep in repair its material, and to develop its traffic, then the experiment must end in utter failure. The advantage will, in fact, for some years be wholly in favor of the private corporations. Their burdens will be no heavier; their machinery and organization will be the more perfect. Under these circumstances they should, as finally putting to rest an issue which hitherto they have regarded with apprehension, gladly accept the test, rather than shrink from it. Finally, the corporations and a large portion of the public have strenuously maintained that, in this country at least, the railroad system could most advantageously be managed, both for energy and economy—as regards the railroads and as regards the community—through private enterprise. This, as they have already intimated, the commissioners are disposed neither to deny nor to concede; it is a subject upon which their minds are

wholly open to conviction. They simply desire to try the experiment. Even those who oppose the public control of railroads upon economical or political considerations, can scarcely object to the trial of so limited and carefully restricted an experiment as that now proposed, if only that they may see their anticipations practically realized. Such an unreasoning antipathy to change would exceed even the conservatism of the British Parliament, which is now preparing to devote the whole railroad system of Ireland to a fair attempt at the solution of this difficult problem. The commissioners have only further to say, that they believe the course they have marked out combines as many advantages, with as few dangers, as any which is likely to be suggested; certainly, if it should prove otherwise, the failure will not arise from any lack of anxious consideration on their part, or from any want of a due sense of the heavy responsibility under which they have been called upon to advise.

JAS. C. CONVERSE,
EDWARD APPLETON,
CHAS. F. ADAMS, Jr., } *Commissioners.*

THE WAR AND BRITISH INDUSTRY.

From "The Builder."

That "history repeats itself," we are forcibly reminded by the appalling incidents occurring at the seat of war, and by the localities in which they have taken place, as viewed by the light of an earlier chapter of French history. The events of to-day recall those of former times; there are important points of difference, doubtless, in the history that is being repeated, but there are also numerous startling coincidences. One hundred and eighty-five years since in this current month of October, the edict of Nantes was revoked, by Louis XIV., who has been variously designated "Most Christian King," "the Great," "the Infamous," "the Cruel," and "the Profligate." The revocation effected a *coup d'etat*, in which the best men of France were slaughtered, sent to the galleys, or driven into exile. The monarch of that time lost his head—he had no heart to lose—inflicted indescribable suffering, and also entailed incalculable loss upon France, by his unwise, cruel, and despotic action. With this self-sufficient and remorseless tyrant originated the well-known arrogant declaration, "*L'etat c'est moi.*" His ruthless misrule made of France a furnace of affliction, a nation of slaves and profligates, a land in which good and free men could not breathe, a paradise for pimps and parasites. It would be ungenerous to dwell upon the points of resemblance between the elements and influences at work at that time and at the present. How startling it is to recall some of the scenes of suffering then—Sedan, Metz, Strasbourg, Tours, Charenton, all have their names recorded; from each a large contingent of the best sons and daughters of France were hunted forth into exile, driven from their own land, to aid with their skill the people of other nations. Many of the refugees fled to Switzerland, Holland, England, and not a few to Prussia, in which the "Edict of Potsdam" was passed to give them welcome, and to secure for them equal rights and privileges. The Royal House of Prussia includes in its lineage Huguenot refugees, and the Queen of England has also the blood of the hunted French Protestants in her veins. Many of the soldiers in the hosts now invading France may be believed to be the descendants of the Huguenots. Have they returned to France inspired by Nemesis? Surely they have had vengeance enough, and would better honor their noble ancestry by now seeking the inspiration of the God of mercy!

Sedan, what sufferings it endured then, and has had to endure again. It was the birthplace of the great Huguenot, Marshal Turenne, whose gigantic statue still stands in its market-place. It was until then the seat of a Protestant university, which was suppressed in the attempt to stamp the Huguenots out of existence and of memory. From Strasbourg have come to England, and have escaped to other lands, many able men. Metz, late a stronghold of French warriors, was a stronghold then of the Huguenot soldiers of the Cross. The United Kingdom, Germany, and other nations owe much to the hunted citizens

of Metz, who, generations since, found refuge there. From the De Chenevix family of Metz and Lorraine, and from another Huguenot stock, the De la Tranche family, Richard Chenevix Trench, present Archbishop of Dublin, is a direct lineal descendant. Tours, menaced but not yet devastated, what a blow was inflicted upon its industry, its moral, intellectual, and religious life, by the Revocation. To speak of its industries alone, its 40,000 skilled workers in the silk manufacture were reduced to 4,000; its 8,000 looms were reduced to 100; of its 800 mills and works 730 were closed. Tours received a blow then, from the effects of which it has never recovered. Fatal, also, was the effect of the Revocation at Lyons, where out of 12,000 artisans, 9,000 of the best men and cleverest workmen fled. Charming Charenton! situated near the confluence of the rivers Seine and Marne, a few short months since one of the most lovely localities in the neighborhood of Paris, or in the world indeed, is now a part of the belt of unsightly desert that surrounds the doomed city. The fiercely unholy Iconoclastic decree that went forth in 1865 respecting Charenton, was a much more barbarous ordinance than the order of 1870, to make waste the borders of the city. Mr. Samuel Smiles, in his interesting work on the Huguenots, thus refers to the doings of the destroyers at Charenton and elsewhere :—"The military *jacquerie* at once began. The very day on which the edict of Revocation was registered, steps were taken to destroy the great Protestant Church at Charenton, near Paris. It had been the work of the celebrated architect Debrosses, and was capable of containing 14,000 persons. In five days it was levelled with the ground. The great temple of Quevilly, near Rouen, of nearly equal size, in which the celebrated minister, Jacques Basnage, preached, was in like manner demolished. At Tours, at Nismes, at Montauban, and all over France, the same scenes were enacted, the mob eagerly joining in the work of demolition with levers and pickaxes. Eight hundred Protestant churches were thus thrown down in a few weeks."

The oppression of Louis XIV. caused the flight of such of the Huguenots as had the means of escape. Many of these refugees found their way to England, but very few of them ever returned to France. The invasion of France which has resulted from the mistake—to state the matter mildly—of the whilom, or present rulers of the country, has caused a large number of the inhabitants of Paris, and of the provinces, to seek an escape from the horrors of war, and an asylum in neighboring States. The permanent results, as affecting the industry of the United Kindom, from the present French exodus, may not be expected to be as extensive or important as those which followed the immigration of the Huguenots. At that time the French were greatly superior to the English, and far ahead of them in various skilled industries.

The refugees, or their descendants, originally established, or greatly improved, some of the most important manufactures prosecuted in the United Kingdom. They introduced the art of paper-making, and erected the first paper-mills of England and Scotland. The descendants of the De Portal family have been for generations, and continue to be, the makers of the paper upon which the Bank of England notes are printed; the Brothers Fourdrinier, descendants of another refugee family, invented the paper-making machine. Crommelin, and others, established the linen manufacture in the North of Ireland. They introduced the silk manufacture at Spitalfields and other places; the fabrication of fancy textile goods at Norwich; the making of felt hats at Wandsworth; of Gobelin tapestry at Fulham; of crystal and glass at Savoy House, near the Strand; of lace and of silk taffetas, and in various departments of skilled industry greatly enriched the nation which gave them an asylum in their time of need. Their descendants have distinguished themselves, and have achieved the highest honor in the departments of legislation and government, of science, literature, theology, law, and finance. They are to be found now in both Houses of Parliament, in the Government of the country, in her Majesty's Privy Council, in deservedly high places everywhere. Names illustrative of this fact crowd upon the mind. Among the peers, Lords Taunton (Labouchere); Eversley (Shaw-Lefevre); Romilly, and other peers directly descended, or connected by blood relationship, with the refugee stock. Again, the names of Hugesson, Layard, Bouverie,

Pusey, Du Cane, and many others suggest themselves. In science, there are, or have been, Papin, Dollond, Roget, Rigaud, and others. In historical, polite, religious, and general literature, Abaddie, Jortin, Grote, Romaine, Drelincourt, Faber, Marryatt, Chamier, and a host of others. We have, or have had, Delane and others, on the press; Fonblanque in statistics; Brassey (Brasseur) and Dargan (Dargent), railway makers; Pigou, as maker of gunpowder; Gillott, of steel pens; Courtauld, of silks; and Courage, of beer.

Such an important, varied, and valuable permanent residue is not to be expected from the present flight of the French; but it can scarcely be questioned that it will exercise a lasting influence in this country on some branches of artistic skilled production. The business relations between London and Paris, and England and France, have of late years been very intimate, and the interchange of products very extensive. Many businesses in Paris and elsewhere have been destroyed; many artistic skilled workers, whose products were, for the whole or the greater part, destined for the London or the English markets, are thrown out of employment — their occupation gone, for a time at least. There are large houses in the neighborhood of St. Paul's and Cheapside that depended entirely upon Paris for the supply of certain descriptions of goods. The supply has been entirely stopped, and the Paris agencies of these houses have been closed. Inasmuch as many of the French people now in London as involuntary exiles have always hitherto been willing workers, and not mere promenaders of the boulevards, it may be supposed that they are unwilling idlers, and that by the exercise of their industry, ingenuity, and activity, they may be enabled to resume production — which they are already doing, indeed, to a partial extent — may form new business connections, and introduce new branches of industry, or extend and improve those already in operation, and remain permanently amongst us.

The effect that the war will have upon British trade cannot of course be known until after its conclusion; it will probably be to stimulate greatly British industry, and to increase production. The disturbing effects of the war are but partially indicated by the last Returns of Trade and Navigation, published by the Board of Trade, which only come down to the 31st of August last. Some of the entries in the return are significant and interesting. As regards shipping, and the entries at British ports, the following items appear:

Entries of Shipping at British Ports in August, 1868, 1869, *and* 1870.

Nationality of Vessels.	Month ending August 31, 1868. Vessels.	Month ending August 31, 1869. Vessels.	Month ending August 31, 1870. Vessels.
Entered:			
Prussian	241	230	60
French	211	212	192
Cleared:			
Prussian	375	277	11
Hanoverians	99	79	1
Mecklenburg	99	73	...
French	377	316	399

Countries whence Arrived.	Month ending August 31, 1868. Vessels.	Month ending August 31, 1869. Vessels.	Month ending August 31, 1870. Vessels.
Entered from:			
Prussia	174	242	182
France	688	733	669
Cleared for:			
Prussia	360	344	10
Hanover	100	103	3
Hanse Towns	234	239	50
France	1,077	1,067	1,433

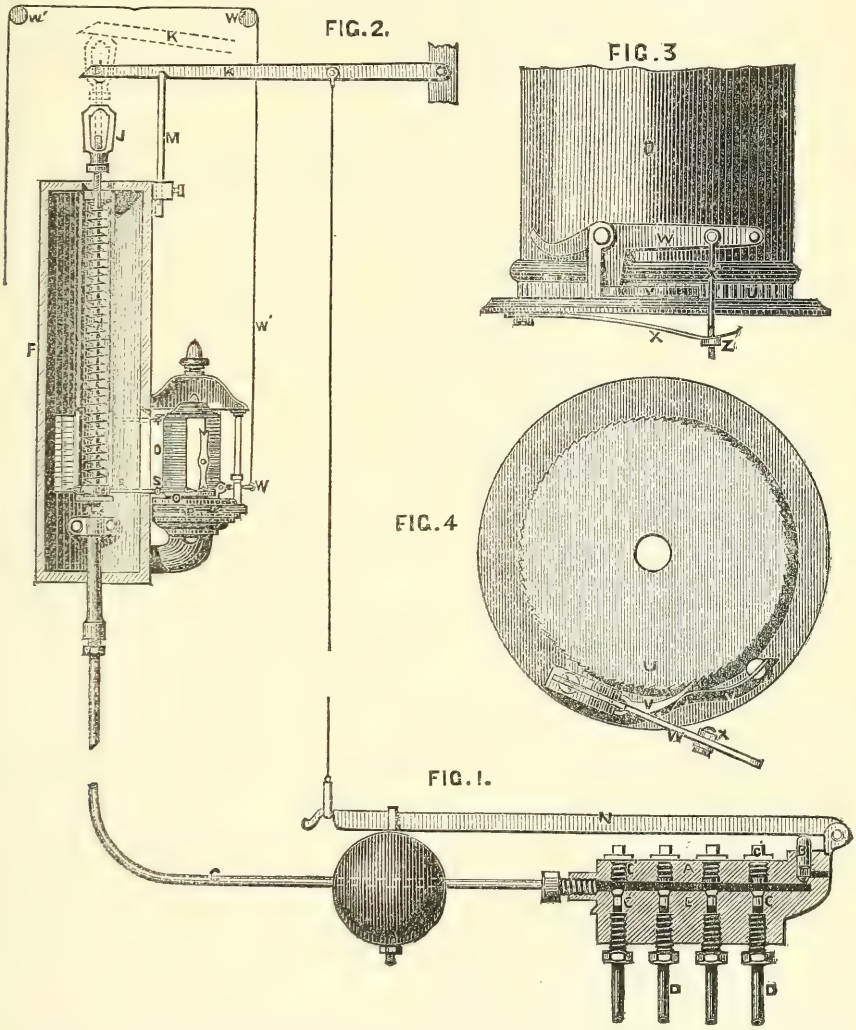
THE ST. LAWRENCE. — It is announced that a new channel, 20 ft. deep, has been discovered in the river St. Lawrence, between Montreal and Quebec. Hitherto the only route for ships of heavy draught has been through a portion of St. Peter's lake, originally deepened at great cost, and maintained at the requisite depth by a large annual outlay. The new channel is reported to be now ready for use, with the exception of a few boulders, which can be removed without much difficulty.

ALL the available force of the Cold Spring foundry has been set to work for the manufacture of 60,000 bombshells. It does not transpire whence the order emanates.

HYDRAULIC PRESSURE METER.

From "Engineering."

We illustrate, above, a mode of working a number of hydraulic presses with but one safety valve standing apart from the pumps, and so arranged and combined with the pressure gauge, that the latter is made to serve the double purpose of registering and assisting the safety-valve in preventing excessive pressure. This arrangement is one which has been designed and recently patented by Mr.



Francis Virtue, of the Liverpool Oil Mills, Liverpool, and its details can be best explained by referring at once to the engravings. In these A is the check and safety-valve casing cast in one, and mounted on a suitable framing and standing apart from the pumps; B is a safety-valve of the ordinary construction; and C, C, check valves for controlling the passage of liquid in the pipes; D, D, by which all the press cylinders communicate with the casing, A, and safety-valve, B. There are four tubes, and consequently four cylinders in the present instance, although a greater

number may be controlled by the same safety-valve, B, if required. The pipes, D, all open into one main channel, E, leading to the safety-valve, B, into which channel the liquid under pressure in the cylinder rises through pipes, D, the check valve, C, being provided to prevent the backward passage of any liquid through either of the tubes, D, in the corresponding cylinder of which the pressure is let down or which is not in action. The channel, E, also communicates with a vertical pressure gauge, F (Fig. 2), by a pipe, G, conveying the liquid to the gauge; C^1 are screw plugs inserted in the holes in casing, A, through which the valves, C, are introduced, and which are adjusted as required to limit the rise of the valves from their seats.

In order to combine the action of the gauge with that of the safety-valve, to assist the latter in controlling the pressure in the cylinder, Mr. Virtue attaches a vertical rod, H, to the indicator, I, of the pressure gauge. In the gauge shown, the rod, H, passes up through the centre of its spring, but without contact with it or with the casing of the gauge. The rod, H, is surmounted by a crosshead, J, which is raised with the gauge indicator as the pressure increases. K is a lever arm mounted on a fixed fulcrum at L, and resting on an adjustable support, M, on the gauge case, with its free end over and in line with the rod, H, and crosshead, J. This lever arm, K, is connected, as shown, with the extremity of the safety-valve lever, N, which is weighted as usual. When the indicator, I, is raised to a certain height, or indicates the pressure to which it is desired to limit the liquid in the cylinders, the crosshead, J, which rises with it, will come in contact with, and raise the end of lever, K, and with it the safety-valve lever, N, thus assisting to open the safety-valve, B, at the desired moment, to prevent the further accumulation of pressure. The crosshead, J, is so attached to the stem, H, that it may be adjusted to raise the lever, K, immediately the limit of pressure required in the cylinder is attained, so that the movements of the levers, K, N, were they independent, would be as nearly synchronous as possible.

The automatical registration for subsequent reference of the pressure attained at each compression of the presses is effected by the following arrangement: A small cylinder or barrel, O, is disposed opposite the pressure gauge scale on a vertical spindle carried on a bracket, P, fixed to the gauge case. The circumference of this barrel is enveloped by a paper lined or marked with a scale coinciding with the ordinary scale attached to the gauge. To the indicator, I, of the latter an arm, R, is attached jointed at S, and provided at its extremity with a socket carrying a pencil or marker, T, which is held by a spring in contact with the scale-marked paper on the barrel. The arm, R, and pencil rise with the indicator as the pressure increases, marking on the paper a vertical line corresponding in height with the rise of the indicator, I. A permanent record of the pressure attained is thus made, the paper being shifted at each compression so as to present a fresh surface to the pencil. For this purpose the barrel, which is capable of being rotated on its spindle with slight friction, has attached to its base a ratchet wheel, U, which is acted on by a spring pawl, V, to rotate the barrel. This pawl, shown more clearly in the detail views, Figs. 3 and 4, is connected by an universal joint to one limb of a lever, W, mounted on a fixed fulcrum carried on bracket, P, to the other limb of which lever a line or cord, W^1, is attached. This line passes over pulleys, W^2, to a suitable projection on one of the press boxes, to which it is also connected, so that the pawl will be operated by the lifting of the lever, W, and rotate the barrel, O, to the extent of one tooth of the ratchet, U, at each rise and fall of the press. X is a spring for drawing back the pawl, V, by lowering the lever, W, with which it is connected by a screwed stem, X^1, as shown. The nut, Z, against which the spring bears, is adjusted for regulating the throw of the pawl, V, V^1, spring for keeping the pawl up against the ratchet, U.

A Powerful Fog Whistle.—A fog whistle of considerable force has been completed at the Phœnix Foundry, St. John's, New Brunswick, for Cranberry Island. It blows regularly 8 sec. per minute, and under favorable circumstances it can be heard at a distance of 30 miles.

ARCHITECTURAL IRON CONSTRUCTION.*

The chief considerations that determine the choice of any material for use in building construction are its suitability for the purpose intended, and the relative economy attending its use when compared with other materials, so that assuming its fitness in other respects, that which may be obtained at the least cost is the best adapted for our purpose. But in order to decide fairly and truly on this important part of the investigation—the part which more than anything else constitutes the essence of the inquiry—we must keep steadily in mind the leading principles, that resistance or strength is the thing that concerns us, and that this strength is the measure of the value. In other words, that the strongest beam. other things being equal, is the best beam. In the design of his work, and especially in his specification, the Engineer or the Architect should consider that he is contracting for a certain amount of strength, or work, and that the quantity or weight of material to be supplied is a matter of comparative indifference; he has to buy so much strength, not so many feet, or so many hundredweights of material. Now, the commercial interest is directly antagonistic to this principle; the object of contractors and manufacturers alike is to sell as much material as they can, and they are generally astute enough to be successful in their object. If it were always stipulated that certain results, that is to say, a certain amount of strength or work should be furnished for a certain price, and if the manner of effecting this were left to the skill of the contractor, an encouragement would be given to the intelligent application of scientific principles, and mere rule of thumb proceeding would in time sink to its proper level. The time is gone past when we could afford to treat such considerations as of little moment. In these days of excessive competition, success is with those who intelligently seek the *maximum* result at the *minimum* cost. We propose, then, to compare and examine the relative cost and properties of the several kinds of beams in use, namely, wood beams, wood combined with iron as flitch beams, cast iron, wrought or rolled iron, riveted plate and lattice girders.

Formulæ.—In comparing the several varieties of beams and girders, we shall employ only the formulæ in ordinary use, having previously satisfied ourselves of their accuracy by actual experiment. In applying them to practice, it must be borne in mind that they indicate proximately rather than impose absolutely the suitable forms and dimensions to be used in construction. Since they are based on experiment, they are liable to be modified from time to time by the ever changing conditions and requirements of construction, and the careful constructor will use them as a guide, where, without them, much would be conjectural; but he will not ignore the valuable teachings of practical experience, nor surrender the habit which has made English engineers unapproachable in the practical department of their work, the habit clinging to them from their workshop years of asking themselves as they design, "If I had to do this work, how could I turn out the best job?" We shall employ the formulæ in general use because they are of easy application, and because they have been generally adopted by the experimenters on the strength of materials. We have tested their accuracy in a large number of experiments conducted to the breaking point, and they are sufficient for all the ordinary requirements of office work. Where roofs and bridges of long span are treated, all the forces tending to produce rupture must be considered, and then the simplest methods of calculation will be shown, so that the investigation can be followed by inspection.

Wood Beams.—A wood girder appears at first sight about the cheapest thing of the kind we can employ; yet, if we regard it from the point of view of strength and work furnished, to say nothing of its liability to destruction and early decay, it is doubtful whether it is actually the cheapest even in first cost. This, of course, applies to the neighborhood of London and other towns; but it might not be the same in those places where timber is abundant, and where it is frequently considered advisable to curtail first outlay,

* Extracts from a pamphlet entitled "Architectural Iron Construction." C. R. Brown, London, 1870.

and to reconstruct from time to time. Judging from the large number of experiments made on wood by the writers on the strength of materials, it would appear that we should be in possession of reliable data in reference thereto, but such is not actually the case. All the tabulated experiments forming the basis of the formulæ employed in estimating the strength of timber, have been made on small sections and short lengths; and the specimens have been selected free from all the defects inherent in the larger scantlings used in building, whence it generally results that when a piece of fair size is actually broken, the strength exhibited is about half the amount expected. Musschenbrœck experimented on pieces $\frac{1}{25}$ of a sq. in. in section, and his results have generally been accepted by subsequent writers on the subject. Mr. Barlow's experiments were conducted on larger sections, and are consequently more reliable, but none of them represented the large masses in constant use. There is a careful and satisfactory experiment detailed by Mr. Edwin Clarke: He broke a piece of timber, 17. ft. long and 12 in. square, with 14 tons on the centre, the supports being 15 ft. apart. Now the formulæ relied on in estimating the strength of timber, and for the centre breaking weight in cwt. $\frac{b\,d^2}{l} \times 4$ where b represents the breadth in inches, d the depth in inches, and l the length in feet, and applying this to the beam in question, we obtain

$$\frac{b\,d^2}{l} \times 4 = \frac{12 \times 144}{15} \times 4 = 23 \text{ tons},$$

the calculated breaking weight against 14 tons—the actual weight furnished by the experiment. The value of the coefficient 4 is evidently much too high, and changing it to the value found in the experiment, we have for the kind of timber in question $\frac{b\,d^2}{l} \times 2.25$, and in this form it will be found generally reliable. But inasmuch as all timber is liable to be "shaky" and weak about the knots, it is not safe to work so near the ultimate strength as in the case of wrought iron, where 4 is taken as the factor of safety. It is better to adopt 5 instead; indeed, Tredgold says that sagging is sure to result where this figure is exceeded.

We have, then, as the cost of 14 tons of strength in timber, 17 feet cube fir at 2s. 6d., £2 2s. 6d.

Flitch Beams. — A wood girder is strengthened by being cut down and reversed, and an iron plate bolted between, thus forming the favorite flitch beam of builders. Here let it be observed that the iron is placed in the most unfavorable form for work. We have the web of a girder, but without the flanges, and assuming the ultimate decay of the timber, it possesses no stability in its form, and the effect of a superincumbent load would be to cant it over. It stiffens the beam, however, and lessens the deflection, and will continue to be used till the time when it is understood that the same amount of metal in the form of a rolled beam would do the work and dispense with the wood altogether. Let us take a beam made up of two $3'' \times 12''$ fir planks, and a $12'' \times 1''$ iron plate bolted between, and test it by the formula: $\frac{d^2}{l}(c\ b + 30\ t)$ = breaking weight in cwt., let b = breadth in inches, d = depth in inches, t thickness of flitch in inches, l = length of bearing in feet, W = breaking weight in cwt. on middle, we have, taking c as 2 for fir

$$\frac{d^2}{l}(c\ b + 30\ t) = \frac{144}{15} \times 42 = 19 \text{ tons}.$$

This 19 tons is the theoretical breaking weight, but those who are familiar with the behavior of iron under such a load know that long before 19 tons were placed on a 12″ plate the side beams would have been thrown off by the buckling of the upper part of the plate. Considerable allowance must, therefore, be made in applying this formula in actual practice, and while the excessive cost of the system is so apparent, there is little inducement to test the actual result of an experiment conducted to breaking point. There is a certain amount of convenience in making connections to these beams, and this is probably the chief reason why they are used, but the same objects may be obtained by rolled or riveted beams at less cost.

Cast Iron Beams.—The first successful application of cast iron in the form of beams on record is that of the cotton mill of Messrs. Phillips & Lee, near Manchester, in 1801. The design was furnished by Boulton & Watt, and, although differing slightly from the present section of greatest strength, was a singular approximation

to the best model, and furnishes another instance of the genius of Watt. Since that time they have been made the subject of exhaustive experiment by Mr. Hodgkinson, Mr. Fairbairn, and others, and every requisite of design, best mixture of pig to produce the strongest metal, and its best distribution in the form of a girder afterwards, is known with certainty. But, unfortunately, it is never known, whatever care is taken, whether the girders when made will be as strong as expected. They are never to be depended on. Founders know that without warning, at times, their best castings will split with a loud report, and this dangerous property is set down as the effect of unequal contraction in cooling, the fact being that cast iron is an unyielding brittle material that should never be subjected to a transverse or tensional strain. An air-hole in castings is a common and a fatal defect, and a thrust tending to twist them, or a blow, is almost sure to fracture them. Serious accidents have happened through their failure ; life and property have been sacrificed; and the recent warning at King's College, where *the whole dining-room was destroyed by the giving way of an imperfect cast-iron beam*, should prevent their use henceforth in any case where wrought iron can be substituted.

The plea generally advanced in their favor is that they are cheap, being only about half the price of wrought iron per ton; but if half a ton of wrought iron will do the work of a ton of cast iron, this apparent advantage ceases, and when the cost of freight, carriage, hoisting, and fixing are taken into account, the advantage is wholly on the side of wrought iron, to say nothing of its freedom from all the drawbacks attending the use of cast iron. For the purpose of comparison we will apply the test of their cost in strength by designing a beam that shall exhibit a corresponding strength of 14 tons on the centre, the supports being 15 ft. apart as before. The well-known formula, $W = \frac{a\,d\,c}{l}$, is the most convenient for this purpose, or indeed for any other investigation of cast iron, riveted plate, or rolled beam. We have used it in the course of a large number of experiments, and have found it reliable and consistent in every instance. It must, of course, always be borne in mind that the coefficient c changes in value according to the type of beam; for example, a small flange would give a higher valve than a large flange, but it does not necessarily follow that the small flange beam is the best beam, and any departure from a given form, or change of other conditions, involves a change in the numerical value of c.

Let W = breaking weight in tons.
" a = area of lower flange in inches.
" d = depth in inches or feet.
" l = length in inches or feet.
" c = coefficient to be ascertained by experiment.

In the case of the best form of cast-iron girder, where the lower flange has about six times the area of the upper flange, it is placed at 25.

For a girder to break with 15 tons on centre at 15.0 between supports, we require 9 in. of area in lower flange, $1\frac{1}{2}$ in. in upper flange, and $4\frac{1}{2}$ in. in web. The weight per foot run would be 50 lbs., and the total weight $7\frac{1}{2}$ cwt. By the formula we have

$$W = \frac{a\,d\,c}{l} = \frac{9 \times 12 \times 25}{180} = 15 \text{ tons},$$

and the cost at 6s. per cwt. would be 45s.

The use of cast-iron girders is steadily decreasing in the neighborhood of London and elsewhere ; they continue to be used chiefly because the size of the lower flange offers facilities for the construction of brick arches; but even in such cases a wrought girder with a wider plate flange, or a Phillips girder inverted, would be cheaper.

Riveted Plate Girders.—The experiments made on various forms of girders in connection with the Britannia Bridge led to a vastly increased use of plate beams. Here, at least, were no hidden sources of danger from flaws or air-holes, the compression of the iron in rolling making this actually impossible, and if the strength, per inch, of the iron were ascertained, the ultimate strength of the beam could be found with the ease of a sum in addition. Mr. Fairbairn experimented carefully to determine the best form for the new girder, and made various distributions of the metal in the flanges and the web, subjecting each example to a breaking test till the proportions had been established correctly ; ultimately the two types adopted were the single web and the box girder. The box girder

seemed at first to offer advantages over the single web, it was stiffer laterally, and took the strain fairly when experimented on. Later experience, however, shows that a better distribution of metal can be made in the single web girder. This is, moreover, free from a serious objection on the score of rust. A box girder once made cannot be painted inside unless it be one of large dimensions, and then only with great difficulty, whereas the accessibility of the web girder in this respect renders it practically indestructible.

In the course of these experiments there appeared an advantage in making the area of the upper flange larger than that of the lower flange, and the practice is very general at the present time. Our experience of girder testing on the large sections in actual use has not led us to the same conclusion. In every case of broken girder we found the fracture occurring in the lower flange when the area of both flanges was the same; consequently, any increase in the metal of the upper flange would have been unavailing in increasing the strength, while it would have been an useless increase of cost. A difference in the strength of the iron used in the experiments would explain the cause of the different results shown. We used the ordinary iron of commerce, manufactured in the ordinary way, and having a tensile strength of 18 to 20 tons per in. At the time of the earlier experiments, a stronger iron was in general use; competition had not reduced the quality as well as the price, and, assuming that the iron then tested had a strength of 24 tons per in. in tension, the different results are satisfactorily accounted for. Unless, therefore, a strength of 24 tons per in. can be depended on (a strength quite out of the question now in ordinary girder plates), it is better to design the flanges with an equal area of metal.

From the "Application of Iron to Buildings" we select two experiments:

A riveted plate beam, 7 in. in depth, with web $\frac{1}{2}$ in. thick, flanges $2 + 2 + \frac{3}{8}$, and weighing 24 lbs. per ft. run, placed on supports 7 ft. apart, yielded with 24,379 lbs. on the centre.

A larger beam, with web 16 in. deep, angle iron flanges $3\frac{1}{2} + 3\frac{1}{2} + \frac{1}{2}$, weighing 55 lbs. per ft., and placed on supports 24 ft. apart, yielded with $14\frac{1}{2}$ tons on the centre. This is an exceptionally low result, and it is probably due to the manner of applying the load. It is at all times difficult to prevent iron beams yielding laterally, or canting over, long before the breaking strain is reached.

Many other experiments are recorded in the same words, and ultimately the value of c was placed at 60 and 74 for single web girders, and 80 for the box girder; and later investigations confirm the general accuracy of these figures. We now record two of our experiments made at Mr. Kirkaldy's works in 1867, where perfect arrangements exist for securing an absolutely accurate result. It will be seen that, although the upper and lower flanges were of the same sectional area, the girder in each case broke across the lower flange through a rivet-hole. Since then we have broken many others, and always with the repetition of the same thing, the fracture through the lower flange starting with some rivet-hole.

Experiment 24. Riveted plate girder, web 12 in. deep, flanges of angle iron only $3 + 3 + \frac{3}{8}$, distance between supports 10.0, length 10.6, weight per ft. 55 lbs., total weight 5. 0. 15.

Set, Inches.	Deflection Inches.	Stress in thousands of lbs.	
....	0. 3	10,000	Fracture
.007	0.11	20,000	across lower
·013	0.19	30,000	flange through
.021	0.26	40,000	rivet-hole, frac-
.051	0 34	50,000	ture fibrous.
.094	0 44	60,000	
.369	1. 1	80,000	
....	....	83,952 lbs. broke	

applying the formula $\frac{w\,l}{a\,d} = c$ to obtain the value of the coefficient we obtain 61, confirming the accuracy of the general value, 60 for this form of girder.

Experiment 29. Riveted plate girder, web 16 inches deep, flanges of plate and angle irons, area of top flange 10 in., area of bottom flange 10 in., weight foot 79 lbs., distance between support 25 feet.

Set, Inches.	Deflection, Inches.	Stress in lbs.	
.....	0.30	20,000	Fracture across lower flange through a rivet-hole, fracture fibrous.
0.0023	0.61	30,000	
0. 072	0 93	40,000	
0 173	1. 3	50,000	
0 5:8	1. 9	60,000	
.....	....	67,335 lbs. broke	

applying the same formula $\frac{w\,l}{a\,d} = c$ we obtain 75 as the value of the coefficient.

The iron of the last two experiments was peculiarly tough and fibrous, yet the fracture occurred in the lower flanges through rivet-holes, and they are conclusive that wherever the principle of equal flanges is departed from, there will be a decrease in strength in a similar ratio.

Lattice Girders.—These are not so strong as the plate girder, since the shearing strains, caused by the load, are less perfectly transmitted to the flanges than in the case of the web girder, and the proper strength of the ties and struts has to be carefully considered. They have an advantage where great depth is allowable, or where long spans have to be bridged over. They are lighter in appearance, and altogether better than plate girders in situations exposed to view. There is a common difficulty in buildings where columns or deep girders are not admissible in providing for the support of a large floor or ceiling. A trussed or lattice girder employed in such cases allows the ceiling and the floors above to be suspended from the lower flange, while the upper flange forms a support for the next floor or the roof, as the case may be.

A light and effective form of lattice girder for large rooms and buildings may be made with spandrels, and the filling or panelling may be designed in harmony with the decorative character of the building. There is no reason why we should continue to use ugly plate web girders, where, without material additional outlay, one's sense of what is fit and becoming may be gratified. It is quite possible to design and to execute a higher order of iron work than we have yet seen. At no time has iron entered so largely into general use as at present. Churches, houses, furniture, roads, and bridges constitute ours essentially an iron age. It is cheap in first cost, and yet susceptible of the highest artistic treatment. We have only to look abroad, in France and Germany, to see what can be done in cast-iron, and our own, as well as the Italian and Flemish mediæval workers, have shown us what can be done in wrought-iron. It may be humiliating, but is nevertheless true, that the country is overrun with detestable examples of bad taste and bad design. It will be urged in extenuation that designers are not always free agents, and that the necessity to construct at the minimum cost has been the cause of the painful examples witnessed everywhere. We recognize the necessity here spoken of, but we protest against the conclusion. The remedy against the continuance of this state of things lies with the architect. His professional training has taught him the true art principles of work, and when he insists on their recognition wherever he is concerned, he not only benefits the nation at large, but he helps to raise the workman from the condition of a mere drudge to that of an intelligent artisan.

The formulæ previously given are not sufficient for lattice girders, since we have to take into consideration the strains in the bars as well as in the flanges. The following, based on the properties of the lever, is sufficient:

Let W = distributed weight, S = strain on centre at top and bottom flanges, L = length of span, D = depth of girder, x = distance of any point from abutment, y = strain on any lattice bar, a = distance of centre of lattice from centre of girder, l = length of any lattice, then $\frac{WL}{8D} = S$ at centre $\frac{W}{2DL}(Lx - x_2) = S$ at any point distant x from the abutment, $y = w\frac{a\,l}{DL}$ for a single triangulation, and must be divided by the number of points of attachment in the base of the triangle, and let w = weight at centre of girder, then $\frac{WL}{2D}$ = strain on all the lattices. The members of these girders should not be strained more than 4 tons per inch in compression, and 5 tons per inch in tension.

Rolled Beams and Solid Flange Girders.—It is said that we are chiefly indebted to a strike among the carpenters of Paris, for the introduction of rolled-iron joists into general use some years ago;

now there is no building laying any claim to excellence, constructed without them either in this country or abroad. From the nature of their manufacture—compressed by powerful rollers while red hot—it is impossible that any defect of air-holes, or the other sources of danger in cast-iron, can exist. They are free from the weakening effect of riveting—a most important consideration, when it is remembered that an ordinary plate girder has often 30 per cent. of the strength in tension abstracted by that operation. They have, moreover, special qualities in themselves which contribute a strength that can never be obtained from riveted girders. The whole section is one solid homogeneous bar, and there is perfect cohesion between the several parts of the flanges and the web; whence it results that the web actually works in resistance to the forces of tension and compression of the load, as well as performs the office of keeping the flanges asunder at a given depth. This is proved by investigating the strain produced by a maximum breaking load, and finding a resistance exhibited, which, if confined to the flanges only, would represent a strain of 35 tons per inch. Now, since we know that the ordinary iron of commerce does not exceed 20 tons per inch of strength in tension, we are bound to credit the web with a certain amount of the work, and if we consider it as a series of layers acting with a proportionate resistance to their respective distance from the neutral axis of the beam, we are able to account for the extraordinary resistance exhibited. Up to depths of 10 and 12 in. they may be used with great advantage; beyond this depth the cost of rolling increases in a much greater ratio than the strength. A gang of workmen has to attend the rolling of each beam, special overhead machinery is required to pass them through the rolls, and they cannot be finished off at one heat. Another disadvantage is found in the inferior quality of the iron in such large beams. There is more difficulty in squeezing out the cinder from such large masses, and the product is always a less fibrous and weaker iron than that produced in the smaller sections. Beyond 10 or 12 in. depth there is an absolute saving in using either a compound girder formed of two or more beams riveted on each other, or even an ordinary riveted plate girder. The various sections and weights are shown in the plates, together with the safe distributed load for different spans. The loads have been determined by experiment, thus: Two beams were placed alongside each other on supports at a given distance apart, and then loaded with pig-iron gradually, and the deflections noted. It was found impossible to break them, they failed by twisting laterally, but a deflection of several inches was considered tantamount to breaking, and the safe load, as stated in the tables, was taken at one-fourth the weight imposed. The amount of safe load indicated does not cause any appreciable deflection in the beams when fixed in a building. Besides their use in floors, they form excellent lintels over openings, where great strength with small depth is required. In setting out the main girders for a building, it often happens that the most convenient place for a girder would be, not over a pier, but just over an opening; a lintel formed of one or two small rolled beams would sustain all the weight, and form no obstruction to the light or to the headway. They make good stanchions, and are extensively used in the mining districts of the continent as props to the roofs of the mines. In alterations of houses they are invaluable; used as shoring and needles, they occupy little space, and reduce the cutting away of floors, and making good of ceilings and cornices to a minimum. Timber $13\frac{1}{2}$ in. square is generally employed for this purpose, while a 6 in. or 9 in. beam would do the work more effectually. In wide openings over windows in town buidings, where light is always desirable, and where it is especially necessary to keep the arch as shallow as possible, a lintel of channel iron may be used, the vertical flange running up behind the brick arch, constituting the facing and forming a socket to receive the ends of the joists. In the alterations of shop fronts and the conversion of private houses into shops, they are equally useful. An ordinary brestsummer of timber, 13 × 15, or deeper, involves a large amount of cutting away and making good; by the use of a shallow girder, of the triple section, the labor is reduced to one-half, and a firm seating afforded for the joists. Another convenient application is where stone or even wood staircases are concerned, as they furnish any required

strength for the strings and landings, with the maximum amount of headway. There are many other applications in every day construction that will occur to the builder and the architect, and frequently short lengths, suitable for lintels or other strengthening pieces, may be obtained from the scraphead accumulating from the cutting of beams, at a nominal cost.

When we first introduced these beams to general notice in this country five years ago, the accuracy of the tables of strength we then published was questioned, the strength claimed being beyond the experience of engineers accustomed to riveted iron beams. We therefore considered it desirable that they should be tested by an undoubted authority, and we had the advantage of Mr. Zerah Colburn's assistance, who has recorded his opinion of their merits in the following letter :

"Messrs. Phillips,
" *Coal Exchange.*

"Gentlemen—The tests which I applied yesterday to five wrought-iron rolled beams of your importation, leaves no doubt whatever in my mind of the entire correctness of the tables which you have submitted to me, of the safe bearing power of beams of the same manufacture. Although my tests were confined to beams of the more usual and useful sections, say $6\frac{1}{4}$ in. and 8 in. deep, and weighing respectively $10\frac{3}{4}$ lbs. per ft. run, the general consistency of all the tabulated results with my own observations, virtually extends the confirmation of actual trial to the whole list. The strains which I applied were much beyond what the usual formula with the very highest constant—80 adopted by engineers, would have shown to be the breaking weight; yet in no instance was the metal ruptured, or visibly injured. Although a certain permanent set in a vertical direction attended the application of extreme loads, the beams failed only by yielding laterally. When fixed in their intended manner, in fire-proof flooring, failure could hardly occur in this manner. My tests were made by applying weights, by means of a lever, in the ratio of 14 to 1, to the beams at the middle of the length between their supports. The strains and deflections thus produced are taken as twice what would be caused by the same weights uniformly distributed between the points of bearing. In no case in the trials did the 'safe' distributed weights given in the printed table, when diminished one-half, as the corresponding weight applied to the middle of the span, cause any permanent deflection whatever. The following example from the tests, may be given as showing the *extraordinary and most unexpected* resisting power of the beams. One of $7\frac{7}{8}$ in. in depth (and measuring $7\frac{1}{2}$ in. between the centre of the top and bottom flanges), and weighing $14\frac{3}{4}$ lbs. per foot, was placed upon supports 13 ft. apart. A weight of 4 tons 4 cwt. was gradually applied at the middle of the span, causing no appreciable permanent set; this to 4 tons was further increased 18 cwt., and to 5 tons 12 cwt., when, on removing the weight, a perceptible set was found to have taken place. With 6 tons 6 cwt., the permanent set was $\frac{1}{4}$ in., and when the load was finally increased to 7 tons $11\frac{1}{4}$ cwt., equal to a uniformly distributed load of 15 tons $2\frac{1}{2}$ cwt., or nearly $1\frac{1}{4}$ tons per running foot, the beam gave way laterally, *without, however, the least perceptible flaw in the iron*, and on removing the load, the permanent set, vertically, was but $\frac{7}{8}$ in. Other trials of the $6\frac{1}{4}$ in. beams, weighing $10\frac{3}{4}$ lbs. per foot, showed nearly as remarkable results. The flanges show no disposition to separate from the web, and the iron is very tough and elastic under great loads.

" I am, Gentlemen,
" your obedient servant,
" (Signed) Zerah Colburn,
" *Member of Inst. Civil Engineers.*

In the following table, where two weights are given, the beam can be rolled to any intermediate weight between the maximum and the minimum.

Example.—A beam 12 in. deep, weighing 43 lbs. per foot, sustains a safe distributed load of 33 tons on a span of 7 ft.

The Phillips Solid Flange Girder.—In the Paris Exhibition of 1867 were exhibited some rolled girders 3 ft. in depth, and nearly 20.0 long; they excited great interest at the time, and led to a very general feeling that English ironmasters were being overtaken. Those who were behind the scenes knew that these productions were made with great difficulty and expense, and that they were regarded by the makers themselves as an extraordinary "tour de force." A practical looker-on could not fail to be impressed

with the conviction that for ordinary use they were inconvenient, and even inferior to a riveted girder; since this could be designed in so large a section with a greater regard to strength in those parts where strength was demanded by any special exigencies. In short, the conclusion was, that they were magnificent examples of mechanical skill, but that they were useless for ordinary requirements. And regarded in the aspect of first cost of production, they were wholly out of the question, being double the cost of the rolled beams of smaller sections. Practically, then, we are limited to the use of beams having a maximum depth of 10 or 12 in., and Messrs. Phillips' invention starts from this point, taking the small beams and building them up into girders of any required strength, while preserving at the same time the advantages of the solid flange.

Safe distributed Load, in tons and decimal parts of tons, for clear Spans or bearings of.

Depth of Beam in Inches.	Weight per foot, in lbs.	7 feet.	10 feet.	13 feet.	16 feet.	20 feet.	23 feet.	26 feet.	30 feet.
4	7	2.117	1.411	1.058	.847	.641	.495	.433	.385
4¾	8	2.799	1.866	1.374	1.119	.848	.654	.572	.509
6¼	11	4.973	3.316	2.486	1.989	1.507	1.292	1.017	.904
....	13	6.037	4.025	3.019	2.415	1.829	1.569	1.235	1 098
7	14	7.182	4.790	3.591	2.873	2.176	1.865	1.469	1 306
....	17	8 969	5.969	4.484	3.587	2 718	2.329	1 834	1.631
8	15	8.566	5.710	4 283	3 426	2.855	2.225	1.752	1 557
....	19	10.191	6.794	5.095	4.076	3.397	2 647	2.084	1.859
8¾	17	9.952	6.636	4.976	3 981	3.317	2 585	2.036	1 810
....	27	15.222	10.148	7.611	6.088	5.074	3.954	3.113	2.767
6	16	7.932	5.288	3.966	3.173	2.404	2.060	1.622	1.442
7	18	8.868	5.912	4.434	3.547	2.687	2.303	1.814	....
....	24	10.572	7.048	5.286	4.228	3.203	2.905	2 162	....
9¼	25	13.224	8.816	6.612	5 289	4.408	3.400	2.975	....
10	32	20.684	13 789	10.034	8.273	6.894	5.253	4.596	4.085
....	42	26.259	17 507	13.130	10.504	7.503	6.669	5 835	5.187
12	43	33.118	22 079	16.559	13.246	11.039	8.411	7.359	6 542

We have seen that the effect of riveting the members in tension is so to weaken the plate, that the girder breaks across the lower flange, notwithstanding that the strength of wrought iron in tension is nearly double its strength in compression, the ratio being as 20 to 12. And this weakening not only extends to the amount of area punched out, but affects the quality of the plate left, so that iron tested after punching fails to exhibit the same proportionate strength for the area remaining. This, however, does not apply to the compressive members of a beam; there the riveting fills out the holes, the edges of the plate butting against the rivets and no weakening ensues.

Now it is manifest that if we can save this riveting in the lower flanges of the girders, we render available the whole sectional area, or what is the same thing, we get the same strength with 30 per cent. less of metal in the lower flange than in the case of the riveted girder. This is the essential principle of the patent girder, but it is not all. The experiments on cast iron beams found an advantage in balancing the forces in tension and compression by increasing the area of the lower flange till it equalled the resistance shown in the upper flange. This equilibrium of forces has always been recognized as an important element in the ultimate strength of beams. The same thing has been attempted in wrought-iron, and notably when the area of the top flange of a riveted girder was increased. We have seen, however, that no corresponding increase of strength ensued, since with equal areas the lower flange always broke, and it does not appear that any marked results have followed the practice. Doubtless there was a gain in keeping that part called the neutral axis—the line where the shearing forces intersect—as near the middle of the girder as could be, inasmuch as the tendency to buckle in the web when loaded would be lessened in inverse proportion to its depth from the point in compres-

sion, and, moreover, it was an advantage in riveting on connections that the riveting should be made in the place least likely to cause weakness in the beam; but nothing definite was known on the subject till Messrs. Phillips demonstrated the value of the modifications effected in their girder in a series of public tests. They, moreover, found that an increase of transverse strength and a proportionate decrease of lateral weakness were obtained when a plate was riveted on the top of ordinary rolled beams, and that when two or more were riveted, the one on the other, a much greater increase of strength was obtained than could have been expected from the amount of metal added. In common with all experimenters, Messrs. Phillips did not at once attain the object sought, and now and then a failure in some part of the experiment pointed out something to be avoided hereafter, but they persevered in their experiments till they had learned the conditions of success and had demonstrated their original claims. We now give particulars of two of the public tests, and append the account of them appearing in the "Builder," with the comments of several technical journals represented on the occasion.

Experiment 14.—Girder A, 20 ft. between supports, depth 8 in., width of lower flange $2\frac{1}{2}$ in., width of upper flange 6 in., weight 20 lbs. per foot run.

Strain	Deflection.	Set.
4 tons.	0 968	0.218
5 "	2.393	1.322
$5\frac{1}{2}$ "	6 68	....
$5\frac{3}{4}$ "	9. 04	....
$6\frac{1}{4}$ "	13. 29	....
$6\frac{1}{2}$ "	15. 27	....
7	web cracked, canted over at end.	

Experiment 15.—Girder B, 20′′ 0′′ between supports, depth 16 in., width of lower flange $2\frac{1}{2}$, width upper flange 8 in., weight per foot, 40 lbs.

Strain.	Deflection.	Set.
10 tons.	0.632	0 178
$14\frac{1}{2}$ "	1 230	0.471
$16\frac{3}{4}$ "	1 712	0.762
19 "	2.832	1.698
20 "	4.362	top plate buckled near centre.

We now insert an experiment on the Phillips girder for comparison with the riveted plate girder (Experiment 24), the distance between supports and the weight per foot run being nearly the same in each case.

Experiment 43.—Patent girder, distance between supports 10 ft., depth 18 in., width of lower flange $3\frac{2}{4}$′′ in., width of upper flange 6 in., weight per foot run 57 lbs.

Stress.	Deflection.	Set.
20,000 lbs.	0. 66	0.030
40,000 "	0.184	0 054
60 000 "	0.310	0.125
80.000 "	0.454	0 250
100,000 "	0.675	0.380
112,192 "	1. 35 end and	canted over, flange cracked.

It therefore appears that economy effected by the distribution of metal in the form of the Phillips girder is as 112 to 83, being about 30 per cent.

At the termination of the first series of public experiments several members of the engineering profession raised the following questions :

1st. Whether an ordinary riveted plate girder, manufactured of the same quality of iron as the patent girder, would yield as high a result?

2d. Whether rolled beams, supported by concrete and brick-work, as in ordinary fire-proof construction, and prevented yielding laterally, would give a similar high degree of strength?

3d. Whether the undoubtedly high results obtained from the patent girder depend on the quality of the iron employed, or on the peculiar form of its distribution?

With the view of determining these points, and making the series completely conclusive, the following experiments were undertaken :

Experiment 42.—Riveted plate girder with flanges 8 in. $+ \frac{3}{8}$ in., angles $3\frac{1}{4}$ in. $+ 3\frac{1}{4}$ in. $+ \frac{1}{2}$ in., web 18 in. $+ \frac{1}{4}$ in., total sectional area 22.50 in., distance between supports 20 in., weight of beam 1,620 lbs.

Sustained a strain in lbs. 74,210, and then buckled up in the centre.

The strength shown, 33 tons on the centre, was very nearly the calculated strength, and confirms the accuracy of the experiments by Mr. Fairbairn and others.

Experiment 43.—Girder formed of two rolled beams riveted together with top plate 8 in. + $\frac{3}{8}$ in. on upper flange, depth 20 in., total sectional area 22 in., length between supports 20 in., weight of beam 1,480 lbs.

Strain in lbs.	Deflection.	Top plate
73,680.	7,250.	buckled.

The results of this experiment were interesting. It was very generally supposed that the new girder owed its strength to the prevention of lateral deflection and buckling afforded by the top plate, and that when a similar girder was supported in concrete or by brickwork, a corresponding amount of strength would be obtained. In this experiment, the top plate was sufficient to prevent lateral yielding, and the beam took the strain fairly, sinking only in a vertical direction. But it was insufficient to contribute much resistance in compression. If we add to the weight applied on centre 7$\frac{1}{2}$ per cent. for difference in sectional area and weight of beam, for the purpose of comparison with the riveted girder, we obtain 35 tons as against 33 tons.

Experiment 44.—Two rolled beams as last riveted together with top plate 8 in. + 1$\frac{1}{8}$ in. on upper flange, depth 20 in., total sectional area in centre 24.50 in., distance between supports, 20 in., weight of beam, 1,630 lbs., sustained a strain in lbs. 100,210, and then broke across lower flange near the centre.

The girder exhibited the distinguishing feature of Phillips' system, the top plate being of sufficient area not only to prevent lateral twisting, but also to equalize the compressive and tensile strains of the beam, and thus to insure the effective working of all the metal employed. The 45 tons sustained in this experiment, against 33 tons sustained by the riveted plate girder, show an advantage of nearly 40 per cent., and the result agrees very consistently with the whole series of previous experiments.

TABLES FOR THE COMPUTATION OF EARTHWORK.

By GEO. B. LAKE, C.E.

Any method which will facilitate the accurate computation of earthwork must prove acceptable to that large class of civil engineers who have charge of the construction of our railways.

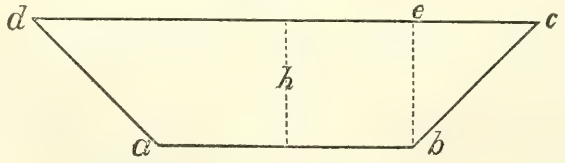
The following method has been in use for some time among a few engineers at the West, but has not become generally known. Its comprehensiveness and accuracy will at once recommend it, as it may be used for *exact computation by the Prismoidal formula;* for an approximation which differs from the Prismoidal formula only by an inconsiderable fraction, and also for computation by "end areas," in the case of preliminary estimates or whenever perfect accuracy is not required.

Let w = width of road-bed.
r = the ratio of side slope.
h = centre height of any cross-section.
l = length of solid whose volume is to be computed.

The area of a level cross-section, as a, b, c, d, (Fig. 1) is

$$\frac{a\,b+c\,d}{2}\times h=\frac{\mathrm{W}+\mathrm{W}+2\,r\,h}{2}\times h=\mathrm{W}\,h+r\,h^2. \qquad (1.)$$

Fig. 1.



The volume of any prismoid having level cross-sections is equal to the volume of the frustrum of a wedge, (Fig. 2), a_1, b_1, f_1, e_1, $-a_2$, b_2, f_2, e_2 plus the volume of two frustra of triangular pyramids a_1, e_1, d_1-a_2, e_2, d_2, and b_1, c_1, f_1-b_2, c_2, f_2.

The volume of the frustrum of a wedge is $\frac{1}{2}\,l\,w\,(h_1+h_2)$, and the volume of each frustrum is by the Prismoidal formula

$$\tfrac{1}{6}\Big[\tfrac{1}{2}\,r\,h_1{}^2+\tfrac{1}{2}\,r\,h_2{}^2+4\,\frac{\frac{1}{2}r\,(h_1+h_2)\times\frac{1}{2}(h_1+h_2}{2}\Big]$$
$$=\tfrac{1}{6}\,l\,\tfrac{1}{2}\,[r\,h_1{}^2+\tfrac{1}{2}\,r\,h_2{}^2+\tfrac{1}{2}\,r\,(h_1+h_2)^2]$$

or, the volume of the two frustra is

$$\tfrac{1}{6}l[rh_1^2 + rh_2^2 + r(h_1+h_2)^2].$$

Hence the entire cubical contents of the prismoidal

$$\begin{aligned}
C &= l\left[\tfrac{1}{2}w(h_1+h_2)+\tfrac{1}{6}r\{h_1^2+h_2^2+(h_1+h_2)^2\}\right]\\
&= l\left[\tfrac{1}{2}w(h_1+h_2)+\tfrac{1}{6}r(h_1^2+h_2^2+h_1^2+2h_1h_2+h_2^2)\right].\\
&= l\left[\tfrac{1}{2}wh_1+\tfrac{1}{2}wh_2+\tfrac{1}{3}rh_1^2+\tfrac{1}{3}rh_1h_2+\tfrac{1}{3}rh_2^2\right].\\
&= l\left[(wh_1+rh_1^2)+\tfrac{1}{2}(wh_2+rh_2^2)-\tfrac{1}{6}rh_1^2+\tfrac{1}{3}rh_1h_2-\tfrac{1}{6}rh_2^2\right]\\
&= l\left[\tfrac{1}{2}(wh_1+rh_1^2)+\tfrac{1}{2}(wh_2+rh_2^2)-\tfrac{1}{6}r(h_1-h_2)^2\right]. \qquad (2.)
\end{aligned}$$

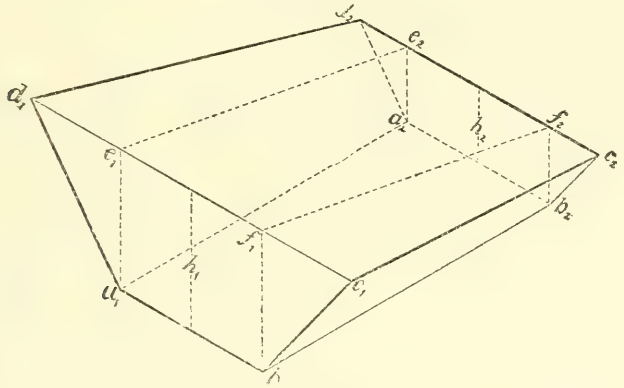
Let it be noticed that the quantity $\frac{1}{2}(wh+rh^2)$ is the volume of a prism having for its base the level cross-section of centre height h for its altitude *one half foot*.

If we neglect the term $\frac{1}{6}r(h_1-h_1)^2$ and place

$$C = l\left[\tfrac{1}{2}(wh_1+rh_1^2)+\tfrac{1}{2}(wh_2+rh_2^2)\right]. \qquad (3.)$$

we shall have the volume of the solid as given by the method known as "averaging the end areas." If now we divide the quantity represented $\frac{1}{2}(wh+rh^2)$ by 27, thus reducing cubic feet to cubic yards,

FIG. 2.



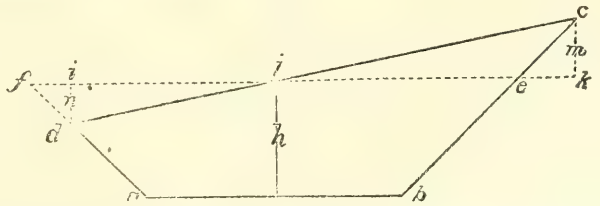
and tabulate the quantities obtained by giving different values to h in the expression $\frac{\frac{1}{2}(wh+rh^2}{27}$, it is evident that to compute by "end areas" we have only to take the sum of the tabular quantities corresponding to the given centre heights and multiply it by the length of the prismoid.

Suppose the width of road-bed is 14 ft. and the ratio of side slope $1\frac{1}{2}$ to 1. A certain prismoid has level cross-sections with centre heights respectively 4.5 ft. and 2.3 ft.

1.7292 = tabular quantity, corresponding to 4'.5.
7432 = " " " " " 2'.3.

247.24 = cubic yards in a section 100' long, as given by the method of "averaging the end areas."

FIG. 3.



By referring to equation (2) we shall see that quantities obtained by this method are, in all cases, too great by a quantity represented by $\frac{1}{6}r(h_1-h_2)^2$, or, in cubic yards, by $\frac{\frac{1}{6}r(h_1-h_2)^2}{27}$.

If, then, we tabulate in another column quantities obtained by solving this expression for different values of h_1-h_2, we shall readily be able to correct the previous computation.

1.7292 = quantity in first column opposite 4.5.
.7432 = " " " " 2.3.

2.4724
0448 = " second " " 2.2.

242.76 = the true volume of a solid 100' long, as given by the Prismoidal formula.

We have thus far considered only the case of level cross-sections. If we have the case where there is a transverse surverse surface slope, we must apply another correction, for the area of the cross-section will not be truly represented by the expression $w\,h + r\,h^2$.

In Fig. 3 let $a\,b\,c\,d$ be the given cross-section. Draw the horizontal line $f\ e$ making $a\,b\,f\,e$ a level cross-section of the same centre height as that given

Area $a\,b\,c\,d$ = area $a\,b\,e\,f$ + area $l\,e\,c$ − area $l\,f\,d$.

Let the difference between the centres and side heights $c\,k$ and $d\,i$ be respectively represented by m and n, then the

Area $l\,e\,c = l\,e \times \frac{1}{2}\,m = (\frac{1}{2}\,\mathrm{W} + r\,h) \times \frac{1}{2}\,m$, and
Area $l\,d\,f = l\,f \times \frac{1}{2}\,n = (\frac{1}{2}\mathrm{W} + r\,h) \times \frac{1}{2}\,n$.
Area $a\,b\,e\,f = w\,h + r\,h^2$.

$$\therefore \text{area } a\,b\,c\,d = w\,h + r\,h_2 + \tfrac{1}{2}(\tfrac{1}{2}\mathrm{W} + r\,h)(m-n). \quad (4.)$$

If we multiply both terms of this equation by $\frac{1}{2}$ and divide by 27, we shall have $\frac{\frac{1}{2}\,a\,b\,c\,d}{27}$ = the content of a prism having for its base the cross-section $a\,b\,c\,d$, and for its altitude one half foot.

$$= \frac{\frac{1}{2}\,(w\,h + r\,h^2)}{27} + \frac{\frac{1}{4}\,(w + r\,h)}{27}\,(m-n)$$

The first term of the last member of this equation is the same as may be found in equations (2) and (3), from which we obtain the tabular quantities in the first column. The second term is a correction to be applied on account of transverse ground slope.

We place quantities found by giving different values to h in the expression $\frac{\frac{1}{4}\,(\frac{1}{2}\,w + r\,h)}{27}$ in a third column, and thus complete the table.

The term $m-n$ is a multiplier which must be determined in each separate case. If we consider n as negative, when the side cutting or filling is less than that at the centre, we may place the term under the general form $m+n$.

The following is a convenient form for the tables. Quantities represented by $\frac{\frac{1}{2}(w\,h + r\,h^2}{27}$, are placed in column A; those represented by $\frac{\frac{1}{4}(\frac{1}{2}\,w + r\,h)}{27}$ are placed in column B; and those represented by $\frac{\frac{1}{6}r\,(h_1 - h_2)^2}{27}$ in column C.

The column marked Ordinate, contains the centre heights.

Base 14 *ft.*, *Slope* 1½:1.

Ordinate.	A.	B.	C.
0 0	.0000	.0000	.0000
.1	.0262	.0662	.0001
.2	.0530	.0676	.0004
.3	.0803	.0690	.0008
.4	.1081	.0704	.0015
.5	.1366	.0718	.0023
.6	.1656	.0731	.0033
.7	.1951	.0745	.0045
.8	.2252	.0759	.0059
.9	.2558	.0773	.0075
1.0	.2870	.0787	.0093
.1	.3188	.0801	.0112
.2	.3511	.0815	.0133
.3	.3840	.0829	.0156
.4	.4174	.0843	.0181
.5	.4514	.0856	.0208
.6	.4859	.0870	.0237
.7	.5210	.0884	.0268
.8	.5567	.0898	.0300
.9	.5929	.0912	.0334
2.0	.6296	.0926	.0370

TO USE THE TABLES.

When the cross-sections are level, take from column A the quantities corresponding to the given centre heights, and from their sum subtract the quantity in column C corresponding to the difference of centre heights.

When there is a transverse ground slope, take from column A the quantity opposite the first centre height.

Multiply the quantity in column B, opposite this centre height by the algebraic sum of the differences between the centre and side heights $(m+n)$, and add the result to or subtract it from the quantity taken from column A according as the value of $m+n$ is positive or negative. Proceed in the same manner with the next cross-section and from the sum of the quantities thus found subtract the quantity in Column C, opposite the difference of central heights.

This gives an approximation which in most cases does not differ essentially from the *exact quantity*. If, however, it is desired to compute exactly by the Prismoidal formula, when there is a transverse ground slope, proceed as before indicated for the end cross-section. Find a similar quantity for the middle cross-section, as follows. Take from column A the quantity corresponding to the half sum of the centre heights, $\frac{(h_1+h_2)}{2}$ and correct by multiplying the corresponding

quantity in column B by half the sum of the values of $m + n$.

Multiply the quantity thus found by 4 and add to the sum of the quantities found for the end cross-sections. $\frac{1}{3}l$ into the sum thus obtained is the *true content* of the solid.

Sta.	Surface.	Grade.	Fill,			$m+n$
			Left.	Centre.	Right.	
1	426.7	428.0	1.9	1.3	0.3	−0.4
2	427 0	429.0	2 4	2.0	1.8	+0 2
3	428.1	430.0	2 4	1 9	1.4	0 0
4	etc.	etc.	etc.	etc.	etc.	etc.

For convenience in computation the value of $m+n$ may be placed in the cross-section book as above.

The determination of the value of $m + n$ is readily understood. At the first station m, the difference between the centre height and the greatest side height is $+ 0.6$. n is $- 1.0$: hence $m - n = -0.4$.

If we assume $w = 14$ ft., and $r = 1\frac{1}{2}$, the computation for the stations given above will be as follows : The quantity in column A, opposite the first centre height, 1.3, is .3840.

The quantity in column B is .0829, which multiplied by -0.4, the value of $m+n$, gives $-.03316$ for the correction to be applied to the first quantity. Hence .3508 is the corrected quantity for the first cross-section.

At station 2, the quantity in column A opposite 2.0, is .6296; and the quantity in column B, .0926 ; giving for the correction .01852, and for the corrected quantity .6481. This added to the quantity previously found gives .9989. Subtract .0045, the quantity in column C, opposite 0.7 ($=h_1-h_2$), and we have for the volume of the prismoid 1 – 2, 100 ft. long, 99.44 cubic yards.

Again, the corrected quantity for station 2 is 6481.

The quantity in column A for 1.9 is .5929 $m + n = o$, $\therefore$ the correction $=$ 0. .6481 + .5929 $=$ 1.2410. Subtract .0001, the quantity in column C, opposite 0.1 ($=h_1-h_2$), and obtain 124.09 cub. yds. for station 2–3.

To compute the tables we may use the formulas before found, but this is a very slow and laborious process. It is much better to use the method of differences, as this is a quicker and easier method and at the same time incurs less liability of error.

The principles governing this method of computing quantities represented by a formula are well known.

If the expression representing the quantity is of the first degree the first order of differences will be constant, and if of the second degree the second order of differences will be constant, and so on.

Hence we see, that for computing quantities in columns A and C, we shall find the second difference constant. For column B the first difference is constant.

We shall also find that these differences do not vary with the width of road-bed, but only with the ratio of side slope.

The following are the differences for the two slopes most commonly used in this country.

Slope $1\frac{1}{2}$:1.

Column A, 2d diff. 0.000555555 +
" B, 1st diff. 0.0013888888+
" C, 2d diff. 0.0001851851+

Slope 1:1.

Column A, 2d diff. 0.000370370370+
" B, 1st diff. 0.000925925 25+
" C, 2d diff. 0.00012345679012+

It will be noticed that $\frac{1}{6}\, r\, (h_1 - h_2)^2$, the expression representing quantities in column C, does not involve w, and therefore the numbers in this column do not vary with the width of road-bed.

Water Supply of Rio de Janeiro.—The Brazilian Minister of Agriculture and Public Works has received a report from Messrs. Andre and Antonio Rebonças, in favor of bringing water to Rio de Janeiro from the Rio Ouro, an affluent of the Rio San Pedro. By this means an abundant supply could be obtained at all seasons of the year. The water would have to be brought a distance of 37 miles. At the point at which it is proposed to tap the Ouro, that river is 833 ft. above the sea level.

Information from the Rolston (N. M.) Silver Mines states that the lead has been traced to a depth of 75 ft., thus setting at rest the fears that those wonderful mines might only be surface deposits.

THE THEORY OF SCREW PROPULSION.

By MICHAEL SEFI.

From "The Art'zan."

A few words of apology may be necessary for writing on a subject which has been given up by many as hopeless, more particularly as it has been repeatedly stated that practical rather than theoretical investigation is required. The author proposes to deal exclusively with common screws, believing them to be, when well proportioned, as good as any other form proposed, and better than a great many. His object in bringing the paper before the society is to get elucidated, as much as possible, certain misty points upon which the theory of screw propulsion depends, and, in the absence of means to carry out experiments, to suggest a way in which those interested may be better prepared than they now are, to draw correct conclusions from any subsequent experiments that may be made; and a means of increasing the present knowledge of the action and results obtained from the screw propeller in ordinary practice by the simple statement, in a manner more lucid than that generally adopted, of the details connected therewith.

It seems to the author, from his little experience in matters connected with screws, that the general tendency is to attribute too great importance to the absolute area of the screw's circle of revolution, to the comparative exclusion of questions of pitch, and area of blades, and their relation one to the other. The ordinary method of computing the probable useful effect of any given screw from the area and velocity of the after stream, is not only very rough but very incorrect, because by taking the area of the after stream by the square of its theoretical velocity as a measure of the thrust, or if the area of the screw's circle of revolution be taken and multiplied by the velocity squared of its theoretical progress due to the pitch, into the revolution per minute, we assume that the pressures per unit of area, the direction of those pressures, and their resultant, are the same throughout. This we all know is not correct. According to the most authentic experiments it has been shown that a portion of each blade varying between .2 and .3 of its total height from the boss is comparatively inefficient. From a certain point in the blade dependent upon the pitch the useful effect of each unit gradually decreases until, where in contact with the boss, it becomes almost absolutely nothing, and that portion of the centre of the plane corresponding to the boss would, of course, represent a negative pressure. It must, from this, be seen that a calculation which omits these considerations is erroneous.

It may be said that multiplying by a coefficient would represent these differences, but it will be seen that this coefficient would have to be different in every individual case, except under conditions of exact similarity in all details.

The area of the blades of a screw may theoretically vary between 0 and $r^2 \times n$ (r being the length of a blade from the tip to the axis of the shaft), yet, *cæteris paribus*, the area of the screw's circle of revolution will be the same in both cases. But the lateral resistance caused by skin friction F will vary as the surface of the blade A; therefore, in the first instance, $E = O$, but in the second it is $= r^2 \times n \times c$, where c is a coefficient of hydraulic friction, varying approximatively as the velocity 1.7 and 1.8, consequently having an absolute value about as the 1.7 and 1.8 power of the distance of each particular unit of area from the axis of rotation. Again, supposing even that the area of the blades, or that of their aft projection, were uniform from boss to tip, as the angles vary continually, the resulting useful effect of each infinitesimal portion must be different. It will, therefore, be seen that the resistances varying with each detail, they cannot be conceived even with any approach to accuracy if if grouped up and expressed in the ratio of pitch to diameter, as now is generally done. Another inaccuracy which ought not to be permitted is the following: It is generally accepted that the blades should not have a greater aft projection than about one-sixth of the total plane of rotation. Accepting this, for the sake of argument, as correct, it ought to occur to those adopting it that the pitch of the screw will make a long difference in such

area S in two screws of the same diameter. Let a = the angle of any part of the screw with its plane of rotation, and x its aft projection: $x : : s : \cos. a : : 1 \therefore S \times \cos. a = x - \cos. a$, decreasing inversely as the angle, it ultimately vanishes, when S would therefore be infinite, and x nothing for the base of very coarse-pitched blades; while, on the other hand, for the tips of fine-pitched blades cos. a may be made as near as we like = 1. The minimum of area denoted by the above expression is thus equal to one-sixth of the plane projections, while the maximum may be almost anything, the diameter, and consequent total area of plane of rotation, being in both cases identical.

Before proceeding further it will be necessary to say a word relative to the action and resistance of inclined planes moving in water. In calculating the resistance opposed by the water to such a plane in the direction of its motion, it is customary to suppose that the resistance varies as the sine^2 of the angle which it forms with its line of progress, upon the hypothesis that the resistance varies as the V^2 of the displacement of the water. An unit of area of the inclined plane in question is supposed at a given V to displace, to a distance equal to the length of the unit into the sine of its angle of inclination, a column of the fluid, having for its base the unit in question, and for its weight that of a column of water of the height due to the velocity of lateral displacement, or to the lineal velocity of the plane $\times$ the sine^2 of its angle. Algebraically expressed, it will be

$$\frac{A \times (V \times \text{sin. } a)^2 \times a}{2g},$$

where A is the area of the unit in square feet, V its linear velocity in feet per second, and a the weight of a cube foot of water. This would be correct if the water were the moving body, because then the linear distance traversed by each particle in attaining a certain height on the plane would bear the proportion of 1 to the sine of a if so measured; but when the water is at rest, and the plane in motion, the linear distance moved is then measured by what would be cos. a. Putting this distance equal to unity, the displacement becomes = 1 $\times$ tan. a. If this be true, it seems to the author that the resistance should vary as the tan. a^2. As an example, supposing that a plane be at an angle of 11 deg. 32 min. with the base, and consequently having a sine = .19994, and giving an inclination of 1 in 5 nearly, disregarding friction, to draw any body when once put in motion at a certain velocity up said plane, the plane being at rest, would require a force = .19994 of the weight of the body; but if the plane be put in motion, and the velocity measured along its base, the body being only free to move in a line normal thereto, under the same conditions, the dynamical force will equal W $\times$ .20406 $\times$ V, .20406 being the tan. of 11 deg. 32 min. Although applicable to solids, when considered with reference to water, it appears to the author that a considerable modification is required. Supposing that the plane be moved along under the weight W, at any velocity V, the dynamical force P required, disregarding friction, = W $\times$ V $\times$ tan. a, but by doubling V it becomes W $\times$ 2 V $\times$ tan a, the dynamical force varying as the velocity. In water W represents the pressure of the fluid upon the plane at any velocity V; by doubling V, P becomes = W^2 $\times$ 2 V $\times$ tan a. Consequently putting Q for the factor of augmentation of V, the resistance to the motion of an inclined plane in water would be as W^2 $\times$ Q V $\times$ tan. a; or putting this in other words, if any given portion of an inclined plane be taken, having a relation of tangent to rad. as 1 is to 2, by moving that plane at a certain V in the direction of its base to a distance equal to its length, a resistance will be overcome, due to the displacement of a body of water equal to its superficial area, to a distance equal to the tangent of its angle. If a solid had been moved, a plane having a rise represented by 1 to 4 of base moved at twice the above velocity would do the same work; consequently the power required will be that to overcome one-half the former resistance to twice the distance in the same time. If with respect to water the theory of the sine were correct, the resistance to the movement of the inclined plane might be arrived at in the same way, but the following results arrived at by Colonel Beaufort show that it cannot.

The following figures show the proportion borne by the effective resistance to that indicated by theory, which is represented by 1. At 30 deg. it was 1.1 to 1;

at 19 deg. 28 min. it was 1.98 to 1 ; at 14 deg. 29 min. it was 3.24 to 1 ; at 9 deg. 34 min. it was 6.95 to 1.

As the theory of the sine ^{2} is nowhere near the truth, it is useless to admit it at all, and a solution of the question should be looked for elsewhere. What the author wishes to advance is that the resistance to all inclined planes may more correctly be expressed as some coefficients of the areas of their plane projection in the direction of motion into v^2 ; the theoretical would then come much nearer the practical resistance than as now calculated. In the example just quoted the area of the plane projection in the direction of motion being reduced by $\frac{1}{2}$, and the velocity increased by its reciprocal, the resistance varying as the simple power of the area, but as the square of the velocity, if it were a simple plane moving at right angles to itself the resulting resistance should be represented by $\frac{4}{2}$ of the former ; of course being an inclined plane it will be less. This is a very rough way of putting the matter, but it would give a better result than calculations according to the theory of the sine ^{2}. In any case, however, it would be excessively difficult to arrive at a very close approximation of the total resistance of any inclined plane at a certain velocity, because experiments made by Mr. Colthurst and others, some years ago, show that greater pressure is encountered by the forward than the aft part of such planes moving in water. Two bodies were drawn by him through water at the same speed of 4.96 ft. per second ; they were furnished with angular prows of the same inclination, viz., having a proportion of base to slant length of 1 to 3.3. One was constructed of exactly half the width of the other, and, being immersed to the same depth of $4\frac{1}{2}$ in., the latter presented double the surface of the former.

By the experiment it was found that the comparative resistances were as 1.89 to 2.51, or nearly 3 to 4 instead of 3 to 6, which would have been the result if the pressure upon each unit of surface had been uniform. The views advanced with respect to the resistance of inclined planes seems substantiated by the indifferent results derived from screws having excessively fine pitches and running at high velocities, and by the glaring incorrectness of the theory involving the sine ^{2}, which was only found to be right at an angle of about 45 deg. In the author's opinion the parts of screw blades at this angle are, for the following reasons, doing the most useful work.

Water is equally mobile in all directions ; consequently, unless the pressure exerted upon its unit of area in all directions is equal, those portions subjected to the greater pressure will recede, which in the case of a screw is called slip, and this may be produced in one of two ways : it it may either result from the water being carried round by the screw, or by its being driven aft. Whichever way the water is moved, of course a loss results. In any portion of the blade of a screw the tendency to drive the water in one direction or the other might geometrically be represented by the sine and cos. of its angle of inclination with the plane of rotation ; and as these will always be one greater than the other, except at an angle of 45 deg., it follows that this angle ought to represent theoretically the inclination of a plane which would distribute the power exerted most uniformly upon the water. Practically, the angle might be something less than 45 deg., as friction would tend to carry the water round with the blades. If the pitch of the blades be uniform throughout, the angle of any part, with its plane of rotation, will of course be at its distance from the axis ; consequently, only one portion of the blade can be at 45 deg., and, if that be the most advantageous angle, the smaller the deviation made from it the better. To attain a minimum of deviation, it follows that this part of the blade should be situated about the middle of its length, as this would divide equally the disadvantages that would result from the coarser pitch consequent upon placing it higher (or nearer the tips) on the one hand, or those induced by the finer pitch consequent upon placing it lower on the other. This gives a pitch of about one and a-half times the diameter. A few experiments, made entirely independently of this conclusion, during the regular working of two steamers running between Liverpool and the Mediterranean, showed this to have been the most advantageous pitch of any tried, other things being the same.

The following are a few details: No. 1 steamer built of iron, in Hartlepool, in

1856 : Length, 210 ft.; breadth, 29 ft.; depth, 16 ft. to main deck, 7 ft. spar deck above; draught loaded, 18 ft. aft, 15 ft. 10 in. forward; carries about 1,100 tons total dead weight ; cylinders, 42 in. diameter, 30 in. stroke; direct-acting inverted; jet condensers; greatest speed in smooth water, with all in perfect working order, 9 knots ; average on voyage with various weather and coal seldom exceeds $7\frac{3}{4}$ knots. Three-bladed iron screw, 12 ft. diameter, 18 ft. pitch ; revolutions, under most favorable conditions, 60 per minute ; average about 57 ; safety-valves loaded to 18 lbs., actual pressure varying between 13 lbs. and 16 lbs., seldom higher ; vacuum, 24 in., occasionally 25 in.; consumption, 19 tons Lancashire coal daily.

This steamer was tried under exactly the same conditions subsequently with an ordinary screw of the same area and diameter, but having a pitch of but 16 ft., and the result was that she fell off half a knot. The consumption increased to 20 tons per day, while the revolutions became 68. On another occasion she was fitted with a similar screw, but having a pitch of 22 ft. The result was that she only averaged 6 knots the whole voyage instead of $7\frac{1}{4}$, that is to say, fell off $1\frac{1}{4}$ knots fully, while the engines went only 48 to 50 revolutions per minute. The pressures carried were in each instance the same.

No. 2 steamer built of iron for same owners, in Hartlepool, in the year 1855 : Length, 182 ft.; breadth, 27 ft.; depth, 14 ft. 6 in.; draught loaded, 15 ft. aft, 13 ft. forward; carries about 630 tons total dead weight. Engines, direct-acting inverted ; cylinders 34 in. diameter, 27 in. stroke ; jet condensers ; vacuum, 26 and 27 ; best steaming in smooth water, $8\frac{3}{4}$ knots ; average on voyages, $7\frac{1}{2}$ to $7\frac{3}{4}$ knots. Screw, common, 3 blades ; diameter, 10 ft.; pitch, $14\frac{1}{2}$ ft.; revolutions, 62. Consumption of Lancashire coal about 14 tons daily. Model of ship sharp and fine at ends. This steamer was afterwards tried with a screw of 13 ft., same diameter pitch, but the results being unsatisfactory, it was resolved to return to the original propeller. Two other steamers with which the author has had more or less to do, built two years ago, and fitted with screws of this pitch, are giving excellent results, as the following details will show : They are sister ships in all respects, built almost simultaneously, and engined by one firm from the same patterns and drawings ; but, like all sister ships, one seems to have a slight advantage over the other in point of speed, and one is a little addicted to priming, a vice that the other is free of. Their length is 270 ft.; breadth, 31 ft. 6 in.; depth moulded, 21 ft. 4 in.; draught forward, loaded, 16 ft. 10 in.; and aft, 18 ft. 4 in.; tonnage, 1,200 register. Screws, cast iron 3-bladed, common type; diameter, 14 ft.; pitch, 21 ft.; length, 2 ft. 2 in.; total area of 3 blades, 59.88 sq. ft.; area of plane projection, 153.93 sq. ft. Engines, direct-acting inverted, 36 in. cylinder, 42 in. stroke ; weight on safety-valve, 40 lbs.; ordinary working pressure, 25 lbs.; surface condensers, vacuum $26\frac{1}{2}$ lbs.; revolutions varying between 50 and 54; average speed about $9\frac{1}{2}$ knots, but whole day's steaming, without any sails and a slight breeze ahead, have shown 10 knots, or 240 to 245 miles per day. On trial trip the maximum speed attained was $12\frac{1}{2}$ knots, the engines making 68 revolutions. A whole hour's continuous steaming showed 12 knots, with 63 revolutions. Average pressure, 29 lbs.; vacuum, 26 lbs.; draught of ship forward, 7 ft. 3 in.; aft, 14 ft. 8 in.

If the before-mentioned results go to prove that the theoretical deductions are justifiable, the blade might well be made proportionately wider than ordinary at that part having an angle of 45 deg., and the tips narrower, as this allows for the greater development of the best portion of the screw, and for the utilization of a greater portion of the available power in a more advantageous manner than would otherwise be the case. To this may certainly be attributed a portion of the improved results sometimes obtained by rounding off the tips of blades, and consequently reducing their area at the extremities ; for, putting aside for the moment questions relating to the pressures induced by the passage of inclined planes at small angles to their line of motion through the water, which are not well understood, as the actual velocity of the outer parts of the blades is in every case, and more especially in that of fine pitches, considerably greater than the theoretical advance due to the pitch, and as the resistance in each direction varies

about as the V^2, it follows that the lateral resistance due to friction increases much faster than the after-thrust, and that the smaller the frictional surface the better. This, therefore, goes to show that the minimum of area of blades necessary for propulsion will be the best, and that fine-pitched screws, revolving at high velocities, are wasteful of power. The friction of water, unlike that of solids, does not depend upon any coefficient of absolute weight or pressure, but upon the velocity with which the body passes through it.

According to Professor Rankine, the frictional resistance R of clean painted iron ships is 1 lb. per square ft. at 10 knots, varying as the velocity squared. According to Mr. Scott Russell this resistance is 1 lb. per sq. ft. per second, also varying in the same ratio. Applying Professor Rankine's computation to any surface of any given area a, the frictional resistance in lb. becomes

$$= \frac{a \times V^2 \text{ (in knots)}}{100}.$$

When applied to a screw, as the friction will vary as the dis'ance^2 of the part from the axis, it is necessary to divide the blades into spaces by ordinates K, say 1 ft. apart, and the calculation becomes

$$a \left\{ \frac{\sqrt{(2\pi r)^2 + P^2} \times x \times 60}{6082.66} \right\}^2 \div 110 = F$$

nearly in lb. where P = the pitch of the screw, a = the area of the space enclosed by any two ordinates, K $- x$ = number of revolutions per minute, F frictional resistance, r distance of centre of area enclosed by ordinates from the axis. And putting

$$a \left\{ \frac{\sqrt{(2\pi r)^2 + P^2} \times x \times 60}{6082.66} \right\}^2 \div 100 = S_1$$

the total resistance in foot pounds becomes

$$\frac{\left(\frac{a1 \times {S_1}^2}{100}\right) \times r_1 + \left(\frac{a^2 \times {S_2}^2}{100}\right) \times r_2 + (an \times Sn), \text{etc.}}{K\, n}.$$

The value of

$$\frac{A\, n \times S\, n}{100}$$

increases as r^2 ; consequently the dynamical force required to overcome it varies as r^3. From this it is easy to see how enormous the frictional resistance may be made by overloading a blade at the tips with surface. The proportions of screw blades with respect to surface are in a more unsatisfactory state than that of any other question relating to screws. In practice the fault seems always to have been to err on the side of two much surface ; consequently the limit of economical area has been reached and passed on that side, and the question that now remains to be determined is the limit of surface on the other side. The question of area seems to resolve itself into one of great surface, S_1, and small pressure, P, per unit of surface, or one of small area and great pressure. The values of P and S, therefore, vary reciprocally, but both vary as r^2. The problem seems to be to determine the most advantageous value of P for the different radii. As every cubic foot of water abstracted from the stern of a ship represents an equal increment of pressure at the bows, tending to retard the speed, it follows that a small quantity of water reacted upon at high pressure is more advantageous than a larger quantity reacted upon at a low pressure point of area. Again, according to all authorities, frictional resistance increases about as the area into the V^2, or into the 1.8 power of the velocity ; but according to the same, the pressure upon an inclined plane moving through water, although varying about as V^2, is not directly as the area, but varies in a smaller ratio. Therefore, after a certain width of blade has been attained, the useless resistance increases faster than the pressure due to the velocity.

With reference to Mr. Rigg's theory of inclined paddles, and repudiation of that generally accepted, of the propeller screwing its way through the water, they appear to the author, to a certain extent, reconcilable one with the other. The ordinary theory takes into consideration the effect of the action of the screw ; Mr. Rigg's, the result of the effect or the deflection of the water by the blades. This seems, however, to have but little to do with the action of the propeller, as such water, after it has once passed it, has nothing to do with the propulsion of the ship. If the screw be supposed working in undisturbed water, the action would be about the same as that of any inclined plane acting in a solid body, the only difference being that the solid body retains its shape after the action, while the particles of water, being free to move in

any direction, naturally follow the line of least resistance or greatest impulse. Summarizing what the author has in the foregoing endeavored to express, the following questions present themselves: In any given screw, what should be the diameter, pitch, and area, and the position of maximum area? It being acknowledged by all that the diameter should be as great as the draught of the ship will allow, this is easily answered. As to pitch, the author hopes to have shown theoretically, and by such few experiments as have been available, that a pitch of one and a-half times the diameter is at least one of the most advantageous. The next point is certainly the most misty. The maximum of area having been attained, the minimum should be determined; what this minimum may be it is excessively difficult to arrive at by inductive reasoning, the more so as it imports into the subject questions relating to the economical speed of the engine. Theoretically, area and velocity vary reciprocally; therefore, a reduction from a given area would have to be made up by an increase of velocity, or *vice versa*. It may perhaps be attained when the work done in driving the engine light at the velocity of the screw, and loss in slip bears a minimum proportion to the total power expended in propelling the ship.

Lastly, the greatest width of blade. This should be in the most advantageous position, and if what has been said respecting planes at an angle of 45 deg. hold good in screws having a ratio of pitch to diameter as 1.5 to 1, it should be about the middle of the length of the blade. In screws of finer pitches it might be somewhere nearer the tips than the line of 45 deg., to avoid as much as possible the broken water left by the stern.

As a simple way of enabling a better judgment to be formed, and of increasing the existing very slight knowledge of the right proportions to be given to different screws, the author suggests that, in the description of every such propeller as given by the engineers, instead of stating only the diameter and pitch, the diameter of the boss be given, also that the blades be supposed traversed by ordinates 1 ft., or in smaller screws 6 in. apart, commencing from the tips of the blades, and that the length of each ordinate and its angle with the plane of rotation be stated.

As an example, he gives the following, which are details of the screws of the sister ships already alluded to:

Pitch 21 ft. diameter; boss, 2 ft.; ordinates 1 ft. apart.

1st ordinate	length	4.65 ft.,	angle	26	deg.
2d	"	4.	"	30	"
3d	"	3 33	"	35	"
4th	"	3.	"	43	"
5th	"	2.65	"	54	"
6th	"	2.33	"	68	"

Consequently, as there are six ordinates to each blade, and 2 ft of boss, the diameter of the screw will be 14 ft.

These dimensions are all easily taken in a few minutes from the drawing of the screw, or if only the lengths of the different ordinates be given they will show the width of the blades at the different portions, and the angles can easily be calculated frem the pitch, either trigonometrically, or by geometrical construction. From this a comparative coefficient might perhaps be deduced about as follows:

$$\sqrt{r_1^2 + r_2^2 + r_3^2} + r\,n^2 \times \left(\frac{S\,S}{n\,K}\right)\left(\frac{S\,\theta}{n\,\theta}\right)$$

where $\frac{S\,\theta}{n\,\theta}$ = sum of the angle divided by their number = the mean angle, and $\frac{S\,A}{n\,K}$ gives the mean area.

Even the most intelligent man might puzzle himself for an unlimited period with the meagre details ordinarily furnished, without being able to make anything out of them; so it is of great importance to the cause of screw propulsion that the above-mentioned system, or something similar, be adopted, more particularly because the immense expense of the experiments necessary precisely to determine what it is requisite to know, causes them to be deferred from year to year, while badly designed screws are being driven at a cost for fuel out of all proportion to the useful effect produced.

The author has proposed that the before-mentioned data be given by the constructors of screws and engines, in conjunction with other details of ship and machinery, and results obtained, as an approach to something definite, and as a step towards giving some criterion by which to judge of different screws. This was shown to be necessary in the beginning of the paper, in mentioning the incorrectness of grouping the resistances to-

gether in the simple terms of diameter, pitch, and velocity.

In writing the present, the author has painfully felt the want of reliable unbiased information, and the scantiness of the details noted on all occasions where screws are dealt with ; and it is necessary to state that this paper has fallen considerably short of what was intended.

With reference to experiments, it would be of but little use to try them by driving propellers of different dimensions in the ordinary way, as they would only be like a repetition of those made in the years 1844–5 with the Rattler and the Dwarf, from which it seems comparatively nothing conclusive has been learned. On referring to an account of these experiments to ascertain the date, the author finds the following statement :

"The most favorable results were obtained from a double-threaded screw of 5 ft. 1 in. diameter and 8 ft. pitch. During one experiment the length was 1 ft. 6 in., and the area 13.3 sq. ft., the speed attained being 8.94 knots ; and it is remarkable that in the experiment following, when the length of the screw was reduced to 1.1 ft., and its area to 8.9 sq. ft., there was comparatively little variation in the resulting speed of the vessel or screw, the speed attained being 9.11 knots. This was the best result of the whole series."

The reduction of area would, in the author's opinion, have given better results, but that cutting away a blade leaves very thick edges to bruise and lash the water about.

The screws experimented upon were all 5 ft. 1 in. in diameter ; the pitches 8 ft., 10.32 ft., and 13.23 ft.; and although the most advantageous area of 8.9 sq. ft. was tried at all these pitches, that of 8 ft., or about one and a-half times the diameter, gave the best result. Having arrived at the conclusions already expressed, without knowing the details of the Dwarf's experiments, the author merely quotes them in corroboration of the ideas advanced. In case of a further series being undertaken, he proposes to the consideration of the Society that they be made somewhat as follows :

That an ordinary screw, say, having two blades, and a diameter of perhaps 10 ft., pitch 15 ft., and length of 1 ft. 6 in., be cast and fitted to a shaft set up in bearings in a basin of a dock, with no more obstruction to the free run of the water than is necessitated by the bearings, etc.; this to be driven by an endless band from the shore by the most powerful and nearest engine available, if possible, of not less than 180 to 200-horse power nominal. The screw first to be driven at a low speed, and its velocity afterwards increased, say, five revolutions at a time per minute, until the maximum driving power of the engine is reached. Each separate speed to be maintained for a space of time sufficient to observe and note the results in a reliable manner ; the direction and pressures of the currents produced being measured by means of vanes or other suitable method. The resistance to turning to be measured by means of a dynamometer on each shaft, the proper allowance being made for friction at the different velocities. The thrust to be measured either under water or by means of a lever in contact with the end of the shaft, reacting upon a dynamometer in any convenient position.

Next, that 4 or 8 (or as many as may be decided upon by those intrusted with the experiment) bosses exactly similar to that of the perfect screw be cast and fitted to the shaft, and tried separately at exactly the same number of revolutions as the screw, the first boss carrying portions of the blades up to 6 in. or 1 ft. from the boss (according to the number to be experimented upon); the second to carry 2 ft., the third 3 ft. of each blade, up to the fourth, which will form a perfect screw, having a diameter of 8 ft. and a pitch of 15 ft. The next 2 ft. of surface will be represented on the perfect screw. The tips of each portion to be struck to the radius of the circle which they describe. If the resistances given by each at the different velocities be carefully noted, the increment of observed resistance can only be due to the increase of area.

It is evident that this method of experimenting might be extended indefinitely according to the inclination of the experimenters and the funds at their command; and the resistances due to each particular division of the blades, and their variation at different velocities, must be arrived at with a much greater degree of precision than would otherwise be possible. It might be advisable to cast the

boss separately and bolt the blades and portions of them to the same in the ordinary way for screws with shifting blades, but as the suggestion is simply in outline it would be useless to occupy the time of the Society with details. The author brings the above suggestion relative to future experiments before the Society, because although all agree as to the necessity for such experiments, no one seems to have any very decided idea of the particular way in which such experiments should be conducted; and in the author's opinion, if tried on a ship and propeller under ordinary circumstances, it would be difficult to know in what particular direction to look for the lessons to be learned, or to separate the reliable portion of the results attained from the influence of extraneous circumstances.

GUNPOWDER—ITS NATURE AND ACTION AS EXEMPLIFIED BY RECENT RESEARCHES.

From "The Engineer."

The discovery of gunpowder is lost in the traditions of extreme antiquity. Popularly this great invention is attributed to either Bacon or Schwartz—the former an Englishman who lived between the years 1214 and 1292, the latter a German, who flourished about a century later. It is, however, generally admitted by those who have made the archæology of explosives a study, that the properties of gunpowder were known in the far East long before the birth of Bacon; the latter, indeed, admits as much by his writings. As Mr. Robert Mallet says: "The impression given by Bacon's account is not that of a man divulging a most surprising and new discovery of his own, but of one referring to a discovery already made by others and known to him, though not, indeed, commonly known." In fact all earlier treatises on this subject refer to something already known although only partially in use. Why this great power, however, was not more universally employed, and how the knowledge of it filtered into Europe, are questions that belong more to the antiquary than the modern utilitarian; and, interesting as the subject undoubtedly is, our space will not permit us to follow it. Our present theme concerns the gunpowder of to-day, not the firework composition used in the "Serpentines" and "Bombards" of the fourteenth and fifteenth centuries. Gunpowder is the chief explosive agent employed in propelling projectiles from fire-arms, whether it is the 600 lbs. Palliser shell, which, driven by a 70-lb. charge, is launched from the 25-ton guns of the Monarch and Captain, or the ounce and a quarter of No. 6, that knocks over the grouse-cock with three drachms of best "Hounslow." In either case the substance is the same in all essential particulars. Our readers are doubtless aware that gunpowder is an intimate mechanical mixture of three chemical substances, namely, sulphur, saltpetre, and charcoal. It ignites at a temperature of about 600 deg. Fahr., when its ingredients undergo chemical decomposition, the result being the generation of a highly elastic gas whose force is much augmented by the intense heat produced by the chemical action. Thus the explosive force of gunpowder may be said to be mainly due to the sudden evolution of two highly heated gases (carbonic acid and nitrogen), the intensity of the force depending upon the rapidity with which the gases are developed. Gunpowder was selected as an explosive agent for fire-arms in consequence of its, comparatively speaking, gradual decomposition. The explosion of other substances known as fulminates, is so instantaneous that no metal could stand the enormous strain thus thrown suddenly upon it, as the cohesive force which binds the molecules of iron or steel together would be destroyed before the inertia of the projectile was overcome. In other words, the gun would burst before the shot started. With gunpowder, on the contrary, the development of the gases is comparatively gradual, and the shot is set in motion before the maximum tension of the gas is arrived at. This action can be easily illustrated by a simple chemical experiment. Place a small charge of gunpowder in a thin glass tube and an equal charge of fulminate in a similar tube closing the ends with a cork; upon the application of sufficient heat by a spirit lamp

to fire the mixtures, it will be found that the glass tube containing the fulminate will be shattered to pieces, whereas the gunpowder will in most cases only blow out the cork. Since the introduction of gunpowder, immense improvements have been made in its manufacture; these, however, have been chiefly directed to increasing the strength or propellant force of the explosive substance without regard to its initial action on the gun. Now, the inflammability of powder is greatly influenced by its physical character. The velocity of combustion, and consequently the intensity of the initial action, depends mainly upon the size of the particles or grains of gunpowder, upon the density or specific gravity of the chemical mixture, and upon the particular nature of charcoal used. The quickness of combustion is facilitated by a small grain and a light powder, while the rapidity of ignition is promoted by a large grain, which by its interstices affords an easy passage through the cartridge to the inflamed gas developed on first firing the charge. So long as artillery consisted of comparatively light pieces and small calibres, the initial action or the strain thrown by the gunpowder on the gun at its first explosion was a matter of secondary consideration as compared with the velocity communicated to the shot at the muzzle; but as guns, projectiles, and charges increased, it became a matter of paramount importance to reduce, if possible, the enormous strain exerted by large charges of powder. No fixed rules, the result of trustworthy experiments, have ever been laid down as to the absolute force of exploded gunpowder within the bores of guns having different calibres, although for many years it has been recognized that the strain or pressure produced by exploded gunpowder, when in large charges, considerably exceeds that of small charges. Thus the maximum strain thrown on an Enfield rifle by the explosion of its charge of $2\frac{1}{2}$ drachms, is probably under 2 tons on the square inch, whereas a charge of the same relative proportion to the projectile would, in an 8-in. gun, exert a pressure of over 20 tons on the inch.

We can see, therefore, that as guns became larger and larger, the difficulties of manufacture increased in proportion to the charge of powder employed, until at length it became not only desirable but absolutely necessary to devise some means of reducing the enormous pressure of the exploding gas. The problem was to procure a powder that would materially reduce the pressure on the breech of the gun, without in any important degree sacrificing the initial or muzzle velocity of the projectile. Theoretically this might be accomplished either first, by altering the chemical composition of the gunpowder; second, by some modification in the mechanical structure of the grains; or third, by a combination of both the first and second methods. The composition of gunpowder has been fixed by many careful experiments, and, although a change in one or more of its constituents might result in producing a less violently exploding mixture, such a result would unquestionably be attended with loss of power, lead to imperfect decomposition, and probably increase the fouling or residue left after discharge. The first method has, therefore, generally speaking, been discarded by all who have been engaged in working out this difficult problem, and an almost universal preference has been given to the second, or mechanical method. This method consists in simply modifying the size of grain and density of the powder.

As we have already pointed out, the more or less rapid inflammation of a charge of gunpowder is greatly influenced by the size of the grains or particles of gunpowder composing it. By increasing the size of the grain we decrease the total surface exposed, and so reduce the rate or velocity of combustion, while at the same time we facilitate the velocity of ignition throughout the whole charge. The effect of this must be evident. At the moment of ignition a comparatively smaller volume of gas will be liberated, although ultimately the total volume may be greater. A charge made up of a number of large grains will liberate less gas at first, as each grain takes longer to burn, and the total surface is less; but the comparatively large interstices between the grains enables the gas first developed readily to penetrate and ignite the rest of the cartridge. Thus, while the velocity of combustion, or sudden explosive power of the powder, is reduced, the rate of inflammation, upon which the muzzle velocity of the projectile mainly depends, is increased. It follows that a larger

grained powder should, theoretically, exert a less maximum pressure, although giving the same average pressure, and, consequently, the same muzzle velocity as that given by a comparatively small grained powder. An increase in the density of the powder operates in the same way as an increase in the size of the grain. The velocity of combustion of a dense powder is less than that of a lighter powder, bulk for bulk, principally from the fact that the texture of the powder is closer, and the gas has less facility in permeating the pores of the substance.

This, then, is the theory of the matter; but in these practical days cavillers are numerous, scepticism rampant, and nothing passes current unless substantiated by the clearest evidence of fact. Indeed, in some cases, fact does not appear to be by any means conclusive evidence. Certain mental organizations are quite ready to doubt the evidence of the senses—it is so difficult to believe where we cannot understand.

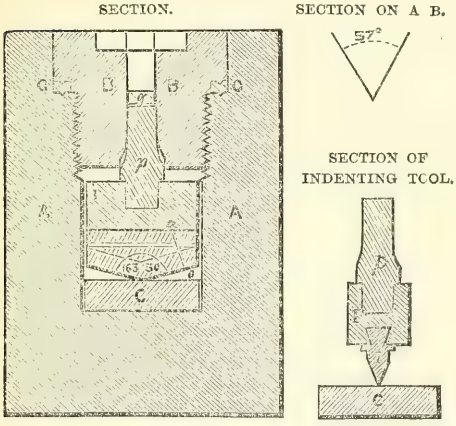
Before, however, we enter upon a discussion of more modern experiments, it will be necessary briefly to review what has already been done to establish the theory of exploding gunpowder. There are three methods by which the explosive force of gunpowder may be arrived at. (1) It may be deduced by estimating the amount of gas which, according to chemical theory, would be produced from a given amount of gunpowder, by combining this with experiments as to the actual quantity of permanent gas generated by the explosion of a small quantity of powder, the heat evolved, and the amount of expansion, at various temperatures, etc. This method, however, which at one time was adopted by Robins, cannot be expected to afford other than a very approximate and unsatisfactory result. (2) It may be deduced by observing the velocity communicated by a given charge to a projectile or a body of a given weight. (3) It may be measured directly. The last method was adopted by Count Rumford in 1792, and the following extract from Major-General Boxer's treatise on artillery will give our readers some idea of the method pursued by this philosopher:

"A barrel of the best wrought iron was made of great strength, its length being $2\frac{3}{4}$ in., and diameter the same, but the size of the bore only $\frac{1}{4}$ in. in diameter; the thickness of the metal was, therefore, $1\frac{1}{4}$ in., or 5 times the diameter of the bore. At the bottom of the barrel was a small projection in which the vent was made. This barrel, being charged with one-tenth of a cubic inch of powder, was placed upon a very firm base constructed for the purpose, and a 24-pounder gun, weighing 8,081 lbs., was placed upright on the top, for the purpose of confining the generated gas. The powder was fired by means of a red-hot ball placed against the vent, and when the explosion took place the barrel was completely burst asunder, and the two halves thrown upon the ground in opposite directions. Experiments were made with a portion of the barrel that had burst, to determine the cohesive strength of the metal, by tearing asunder a piece having a certain sectional area, and he found that the weight per square inch of section required to tear asunder a bar of this iron was 63,173 lbs. Estimating the sectional area of the barrel burst by the gunpowder, and taking the pressure of the atmosphere as 15 lbs. upon the square inch, he reasons that the force exerted to rend the barrel must have been 54,750 atmospheres, and that the force of the elastic gas when first produced was probably more than this, as he conceived that it was not wholly expended in bursting the barrel, and also that it had expanded considerably before the bursting. The following experiments were afterwards made under his directions by Mr. Reichenbach. The gunpowder was fired in a machine of a similar construction, and instead of filling the bore it was put in in such quantities as to have a certain ratio to the whole space. These experiments were made for the purpose of determining the correctness of Robins' hypothesis with regard to the ratio which existed between the elastic force of the fluid and its density, this force being measured by the raising of a weight. Count Rumford attempted therefrom to prove that the elastic force of the fluid was not as the density, but that the elasticity increased more rapidly; and further, that when first generated, it was greater than the amount at which he had previously assumed it, being upward of 100,000 atmospheres. He finishes his remarks upon the subject by endeavoring to show that this enormous force was principally

due to the expansion of the watery vapor or steam contained in the gunpowder."

It is scarcely necessary to say that this method, however ingenious, would be totally inapplicable to the explosion of large charges of powder, and any inductive reasoning from the results obtained with one-tenth of a cubic inch of powder would be valueless if applied to estimate the effects produced by the bolster-like charges which are now consumed in many of our heay guns. It is unnecessary, therefore, for us further to consider Count Rumford's method, beyond remarking that he founded his conclusions on what appear to be erroneous principles. We have no evidence of any further attempts to measure directly the force of gunpowder until the year 1851, when Captain

FIG. 1.



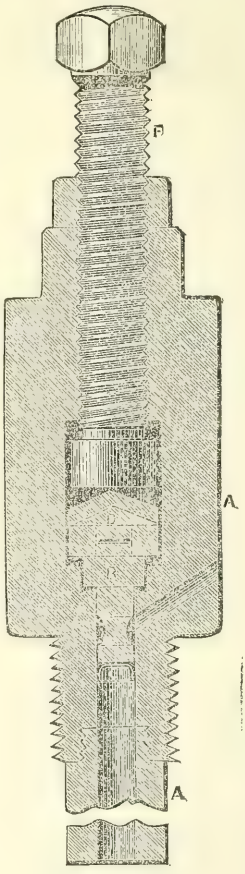
(now General) Rodman, of the U. S. Ordnance Corps, invented his celebrated pressure gauge, which may be briefly described as follows. We quote General Rodman as far as possible. There are two forms of Rodman gauges for determining the pressure of exploding gunpowder, namely, the internal and the external gauge.

The internal pressure gauge (Fig. 1) consists of an outer cylinder A, a screw plug B, for closing the mouth of the outer cylinder, copper gasket G, to form gas-tight joints, specimen of copper to be indented C, indenting tool I, indenting piston *p*, gas check *g*.

This apparatus is placed wholly within the bore of the gun, being inserted in the bottom of the cartridge bag, and having the charge filled in over it, so that no powder should get under it, and come between it and the bottom of the bore when rammed home in the gun.

In using this instrument, all its parts, except the exterior of the outer cylinder, are carefully cleaned before each round, and the threads of the screw plug and the indenting piston carefully oiled; the cop-

FIG. 2.



HALF SIZE.

per specimen is then placed in the bottom of the cylinder, the indenting piston inserted into the screw plug; and, with the outer cylinder horizontal, the plug is screwed home, being afterwards tightly set in with a wrench, while the cylinder is held in a vice. The cylinder is then carefully set down upon its closed end, and the indenting piston gently pushed down till the point of the indenting tool rests upon the copper specimen; a small gas check is then inserted, mouth outwards,

till it rests upon the end of the indenting piston. It gives additional security against the passage of gas to place a small wad of cotton or tow over the gas check, pressing it in firmly, without driving.

The instrument is then inserted into the gun, with the screw plug towards the muzzle, and is generally found in the bore of the gun after its discharge, when the screw plug is withdrawn, and the specimen removed, having an indentation in its surface, due to the pressure that has been exerted upon the outer end of the indenting piston. The indications of pressure are found to be, generally speaking, something less for equal charges by this instrument than by the external gauge.

The external gauge was that generally used by Rodman during his experiments, and is shown in Fig. 2. At any point in the gun where it is desired to ascertain the pressure exerted by the exploding charge a hole is drilled, and the tube A is screwed into the gun, its open end being flush with the bore. The other end is closed with a fitting piston B, the joint being rendered tight by means of the gas check C. The piston moves a knife D, and upon the knife rests a piece of copper E, which is screwed tightly against it by the screw F. When the gun is fired the gaseous pressure on the base of the piston forces the knife into the copper, and the indent produced is a measure of the pressure which has acted upon the base of the piston.

The indenting tool should have a snug working fit in the upper part of the hole communicating with the interior of the bore. The hole in the body of the instrument, just below A, and the recess round the stem of the indenting tool which it enters, are for the purpose of letting out any gas that might pass the piston, and thus prevent its acting against the shoulder of the indenting tool.

As we have already said, the pressure exerted upon the inner end of the indenting piston forces the point of the indenting tool or knife into the copper disc when the gun is fired. This disc is then removed to an ordinary testing machine, and the pressure required to produce an equal indentation with the same tool in the same disc, or in one taken from the same bar of copper, is accurately ascertained; then, knowing the area of the cross section of the indenting piston, the pressure per square inch is calculated.

Rodman's gauge has been largely employed in America, Russia, Prussia, France, Belgium, etc., etc., and the results obtained by its use, although sometimes satisfactory, have shown an extreme variability. The chief objections to this method may be stated as follows: The Committee on Explosives consider that (1) "The shape and size of the Rodman knives and coppers render it imperative to place them at the upper extremity of the plug, and consequently on the exterior of the gun; the gas has, therefore, a considerable space to travel through between the powder chamber and the instrument; thus before reaching the latter it has attained a high *vis viva*, especially in quick burning powders. This is transferred to the knife, and the recorded pressures are always much higher than should be the case." (2) The cut in the copper specimen does not appear capable of being measured with great precision. (3) There must be considerable difficulty in securing uniformity in copper plates of the size used.

Lastly, we have the crusher gauge, a description of which will be given when we consider the proceedings of our own Special Committee on Explosives.

Among the numerous experiments carried out by General Rodman with his pressure gauge, was one to determine whether the pressure exerted by fired gunpowder partakes more of the nature of a blow or of a rapidly increasing pressure in its effect upon the gun.

A slowly applied pressure of a given intensity will produce a certain indentation in the copper specimen, and may be repeated almost indefinitely without perceptibly increasing that indentation, so long as the maximum pressure remains the same. When, however, the impressed force is of the nature of a blow, every succeeding blow will deepen the indentation. General Rodman found that with the powder he used there was no perceptible enlargement in the cut produced in the copper, when the same specimen was used again and again. We understand that this experiment has been verified, both in Russia with the Rodman gauge, and subseqently in this country with the "crusher" apparatus. It is said indeed that in some cases, with very quick pow-

ders, a slight change was noticed in the specimen after each discharge, while with slowly igniting powders there was absolutely no variation whatever.

These experiments seem to indicate that, except in the case of very violently exploding gunpowders, such, for instance, as our *poudre brutale* or R. L. G., although the pressure exerted by exploded gunpowder is developed with very great rapidity, yet it does not, in its effect upon the gun, partake of the nature of a blow. The methods which come under the second head, or velocity trials, have been very numerous. Robins, and subsequently Hutton, attempted to arrive at an expression representing the absolute velocity and expansion of exploded gunpowder, by observing the initial velocity of a projectile of known weight, and then speculating on what force must have been exerted to cause the observed effect. The conclusions, however, arrived at by these philosophers were exceedingly conflicting, a result which is not surprising when we reflect that the means at their disposal were extremely inadequate, and that the theoretical determinations of their constants were founded upon purely hypothetical data of very doubtful accuracy. It is unnecessary for us to enter into a consideration of the many theories advanced to account for the observed effects of gunpowder. The subject possessed a great interest for the speculative philosopher, and was from time to time treated of by Bernouilli, Euler, Lagrange, Piobert, etc., all mathematicians of the highest order. The first purely practical attempt to ascertain the approximate pressure of fired gunpowder in cannon was made by Dahlgren. This United States naval officer caused a number of holes to be bored at certain intervals along a gun, so that a communication was established between the outside and the inside of the gun. Pistol barrels were screwed into these holes, and the length of each barrel so arranged that all the bores were of equal length. This was attained by using short barrels at the breech end of the gun, and longer ones towards the muzzle.

The gun thus fitted was loaded with its service charge and projectile, each of the pistol barrels being charged at the same time with a spherical leaden bullet.

A baulk of wood was arranged so as to intercept the fire from the pistol barrels. The gun was now fired, and the pistol bullets each received an impetus proportional to the pressure of the gas at the particular point at which the corresponding barrel was inserted. Thus the penetration of the bullets into the wooden baulk became a sort of rude measure of the pressure of the powder, and led Dahlgren to construct his guns accordingly. The Belgians have recently made some attempts to improve upon this method by observing the velocity of each bullet a short distance in front of the barrel, as well as the velocity of the gun projectile close to the muzzle.

The following was the method pursued: Having selected a gun for the experiments, holes were bored at various distances, say a caliber apart, commencing from the end of the powder chamber.

These holes are along the side of the gun, and perpendicular to the axis of the bore. The holes are tapped with a screw, so as to receive either a plug to close them, or a hollow tube or gun-barrel from which cylinders are fired.

The gun-barrel is provided with an exterior screw and shoulder, so that when screwed home in its corresponding hole, the extremity is flush with the interior of the bore of the gun. Each hole is provided with a corresponding barrel, and all the barrels are constructed alike, of exactly the same length and diameter. The cylinders are of steel, hemispherical headed, and of equal weight and diameter, the latter being something smaller than the calibre of the barrels, so that the cylinders may be inserted with very little windage.

The experiments were made in the following manner: One of the screw plugs —suppose that just in front of the trunnions — is withdrawn; a cylinder is placed in the corresponding barrel, the end of the cylinder being flush with the bottom of the bore of the barrel. The gun is then loaded with its charge of powder and a projectile. The barrel is screwed home into its hole. The gun is directed so that the shot will pass through the two wire screens of an electro-ballistic apparatus, and that the cylinder when blown out by the explosion will pass through a second pair of wire screens, communicating with another electro-ballistic apparatus. Thus the velocity of both the shot and the cylinder are ob-

served at a short distance from the gun. These velocities are then corrected for the loss due to the resistance of the air during this short interval, and we thus obtain the initial velocity. The results thus obtained afford data for a very intricate and laborious calculation, by which the pressure is arrived at.

Another method of ascertaining the velocity of the projectile at different parts of the bore, and thus inferring the pressure, may be described as follows : A gun is selected, say of twenty calibres length of bore. A certain number of projectiles are procured of exactly the same weight and diameter. For this purpose common shells are the most suitable, as they can always be brought to the required weight by being filled with sand, etc. The charges are determined on, say, one-fifth and one-tenth the weight of the projectile, and a certain quantity of powder of the same date of manufacture is procured, in order that all the experiments may be made under identical circumstances. The velocity of five or more rounds with each charge is then observed, after which one or two calibres in length are cut off the gun and the velocity again observed. In this way the gun is cut down by degrees, the velocity being observed after each operation. The results give a series of velocities corresponding to different lengths of bore, but as these velocities were necessarily observed on several days, and thus under different circumstances, which may affect their accuracy, it will be necessary to lay them down on a curve, the velocities as ordinates, the lengths of bore as abscissæ, and make the necessary corrections by interpolation and differencing. The result will be a curve representing the velocity of the projectile at different distances in the bore. The mean pressure per sq. in. can then be calculated in the following manner :—The total amount of work necessary to produce a velocity, V, with a pressure, p, and in a time, t, during which the projectile moves over a space, s, will be given by the equation

$$p s = \frac{W V^2}{2 g},$$

and the total mean pressure, p, will be

$$p = \frac{W V^2}{2 g s}.$$

Thus, let us suppose we have a gun of 10 ft. length of bore, firing a cylindrical rifled projectile of 9 in. diameter, and 250 lbs. weight, with a charge whose length is 12 in., the initial velocity being 1,200 ft., the mean pressure per square inch will be given by the equation

$$p = \frac{W V^2}{4480 g \pi r^2 (l-a)},$$

in which P = the required pressure per square inch in tons.

W = weight of shot in lbs.
V = initial velocity in feet.
r = semidiameter of shot in inches
l = length of bore in feet.
a = length of cartridge and wad, in feet.

Substituting the above values, we have—

$$P = \frac{250 \times 1200^2}{4480 \times 32.191 \times 3.1416 \times 4.5^2 \times (10-17} = 3.5).$$

In this manner it is possible to determine the approximate mean relative pressure of the gas in the bore. This method has, however, been objected to for the following reasons :

1. When the gun is reduced in length as far as the shot chamber, there will be considerable difficulty in measuring the initial velocity of the projectile.

2. As the bore becomes very short the projectile will receive a certain increment of velocity from the onward force of the powder outside the gun, and there is no direct means of measuring this extra velocity.

3. In consequence of the labor entailed in cutting down the gun, the experiments must necessarily be spread over a considerable time.

4. This method entails the destruction of the gun.

If not the first, one of the first instruments intended to measure the successive increments of velocity impressed by the expansive force of the ignited charge upon the shot from the time it leaves its seat in the gun until it reaches the muzzle, was Rodman's velocimeter.

The principle of this instrument depended on the mechanical law that no connected system of bodies has the power of changing the position of its centre of gravity ; and that the same force will impress upon different bodies equal quantities of motion in equal times, irrespective of their masses. The velocimeter consisted of (1) a cylinder, mounted in a frame, and capable of receiving a uniform motion of rotation about its

axis; (2) a movable slide carrying a marking point so placed as to move parallel with the axis of the cylinder. The instrument, as used by Rodman, was only applicable to smooth-bore guns of a size that could without difficulty be slung in the gun pendulum. The cylinder was firmly fixed with its axis parallel to that of the gun, and at such a distance in its rear as to be below the arc of recoil.

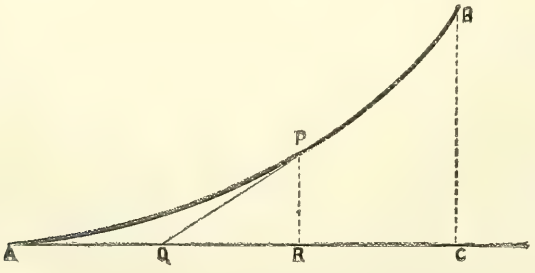
Our space will not admit of a detailed description; briefly, therefore, the cylinder was set in motion, and the gun on being fired moved the marker in its recoil, thereby describing a curved line or helix on the surface of the cylinder. The ordinates and abscissæ of this curve gave a relation between time and space from which the velocity of the shot was determined.

In 1858 Sir Joseph Whitworth designed an apparatus intended to measure the explosive force of gunpowder by registering the recoil of a gun. The instrument, we believe, consisted of a metal disc about one foot in diameter, to which a rotation of about 30 revolutions a second was given. The disc was faced with paper, upon which a marker or pencil travelled under the guidance of the long arm of a lever, the short arm of which was moved by the gun in its recoil By this means it was expected that a time curve would be traced on the disc. Various arrangements, based on Rodman's velocimeter, have, we believe, been proposed from time to time, but hitherto the difficulties of reducing theory to practice have been insurmountable. Theoretically it is quite possible to attach a rod or wire to the shot in such a manner that, on motion being communicated to the projectile, a curve might be graphically described on a cylinder revolving at a known rate. It is evident that the ordinates and abscissæ of this curve would enable us to compute the velocity of the projectile at any instant. Very great practical difficulties would, however, attend this method. If attached from the rear the rod or wire must pass through a vent in the gun, through the cartridge, and be firmly secured to the shot. It would be liable to stretch, break, bend, burn, or otherwise become unserviceable. It would appear more feasible to attach the wire, in the shape of a stout iron rod, to the front part of the shot, and so cause it to mark on a revolving cylinder near the muzzle.

The blast of the discharge might, however, interfere with this arrangement, added to which great difficulty would be experienced in causing a cylinder of the necessary size to revolve with sufficient rapidity. Provided, however, the practical difficulties were overcome, this method would give us a true relation between time and space. Thus, let us now suppose a pencil to be attached to a shot in such a manner that on the motion of the projectile the pencil should move along the surface of a paper-covered cylinder arranged with its axis parallel to, or in prolongation of, the axis of the gun.

It is evident that the line drawn by the pencil would be straight, provided the cylinder were at rest, and that it would be curved if the cylinder were revolving.

Let us assume that the cylinder be made to revolve, that its rate, V, is known exactly, and that the pencil describe a curve, A B, so



The velocity, v, of the shot at any point of the curve, P, for instance, will be found by drawing a tangent and perpendicular from P to Q and R.

Then $$v = V \frac{P\,R}{Q\,R}$$

Similarly if the curve A B represent the whole time, T, of the shot in passing

through the bore, the time, t_1, of passing from A to P will be

$$t = T \cdot \frac{A R_1}{A C}$$

By this means we can ascertain the velocity with which the shot is moving at any instant, or, which is the same thing, the times of passing over successive spaces.

Let us now assume the bore of the gun to be divided into a number of equal small spaces, say the tenth part of a foot, and the pressure to be uniform over these exceedingly short intervals. Calling l the length of the bore from the base of the shot to the muzzle, n, the number of equal parts, v_1, v_2, v_3 . . . . $v\,n$, the velocities of the shot at the end of each interval, P_1, P_2, P_3. . . . $P\,n$, the corresponding pressures; we shall have

$$\frac{l}{n} = S$$

$$P_1 = \frac{W}{2\,g\,S}(v^2{}_1)$$

$$P_2 = \frac{W}{2\,g\,S}(v^2{}_2 - v^2{}_1)$$

$$P_3 = \frac{W}{2\,g\,S}(v^2{}_3 - v^2{}_2)$$

$$P\,n = \frac{W}{2\,g\,s}(v_n{}^2 - v_n{}^2{}_{-1})$$

where

v = velocity in feet per second.
g = accelerating force of gravity in feet = 32.2 ft.
W = weight of the shot in lbs.
l = length of the bore in feet.
P = total pressure in pounds.

If we desire to reduce this to pressure in tons per square inch, or p.

$$p = \frac{P}{\pi\, r^2\, 2240}$$

where

p = pressure in tons per square inch.
π = 3.1416.
r = radius of shot in inches.
P = total pressure in pounds.
224 = number of pounds in a ton.

It appears from the above, that to estimate pressure by this means, it is necessary to know the length of bore of the gun, the weight and diameter of the projectile, and the velocity with which it may be moving at any instant during its passage through the bore. In our next impression we shall speak of the labors of the Special Committee on Gunpowder.

DESCRIPTION OF THE COFFER-DAMS USED IN THE THAMES EMBANKMENT.*

From "The Building News."

The breadth reclaimed from the river by this portion of the Embankment varied from 110 ft. to 270 ft.; the depth of water, when the tide was low, in front of the wall averaged 2 ft., and the rise of tide was 18 ft. 6 in. The borings showed the bed of the river to consist of sand and gravel, resting upon the London clay, at depths varying from 21.58 ft. to 27.10 ft. under low-water mark, whilst the foundation of the wall was in all cases designed to be carried down to a depth of 14 ft. under low-water mark. It devolved upon the contractor to design dams to the satisfaction of the engineer, who reserved to himself the power to adopt either caissons or coffer-dams. The author considered that dams of timber and puddle would not only be cheaper, but could also be more expeditiously constructed, than iron caissons; and having succeeded in obtaining the engineer's sanction to one of the plans which he submitted, the work was begun.

The Temple Pier was the most important work in the contract, and it was therefore requisite to lay its foundation dry as soon as possible. To effect this, two short dams, one at each end of the pier, completely enclosing a short length of the river wall, were first begun. No. 1 was 11 ft. 6 in. long by 25 ft. broad, inside measure, and No. 2 was of similar breadth, but a few feet longer. These dams consisted of two rows of piles of whole timbers, averaging 13 in. square, with a clear space of 6 ft. for puddle. The piles were from 40 ft. to 48 ft. in length, having cast-iron shoes 70 lbs. in weight, and were driven 4 ft. into the clay. Cast iron was used in preference to wrought iron for the shoes, as giving, at an equal cost, a much larger basis for the timber to rest upon. Where the driving

*Abstract of paper read by Mr. T. D. Ridley, A.I.C.E., before the Institution of Civil Engineers.

was difficult, shoes having cast-iron bases and wrought-iron straps were employed. The piles were secured by 3 rows of walings of whole timbers, 13 in. to 14 in. sq., through which and passing through the puddle space, at distances of 6 ft. 6 in. horizontally, were bolts 2 $\frac{1}{2}$ in. in diameter in the lower waling, and 2 in. in diameter in the middle and upper walings. Cast-iron washers, 9 in. in diameter and 2$\frac{3}{4}$ in. thick, were used to distribute the pressure over a large surface of the walings. To avoid the difficulty of having to procure a number of long timbers, the piles were in a few cases only of the full length required, and the others, after being driven, had lengthening pieces fixed to them, so as to raise the dam to a height of 4 ft. above the high-water line. Before proceeding with the construction of these 2 dams the ground was not dredged, but in all the dams subsequently constructed the sand and gravel were cleared off to the level of the clay before the piles were driven. Where the ground had not been dredged, great difficulty was experienced in driving the piles, and in the two dams in question $\frac{1}{6}$th of the whole number pitched, having shown symptoms of failure, were drawn. In all cases the piles so drawn were observed to have cast their shoes, and their lower extremities were usually bruised into a mass of tangled shreds. The failure generally occurred when the piles were passing through a bed of compact sand, resting upon coarse open gravel. Beneath the gravel, and resting upon the clay, was a layer of septaria, which offered a serious impediment to the passage of the piles ; but when once the clay was reached, the driving was comparatively easy. The space between the piles was dredged to the level of the clay and filled with well-tempered puddle. The transverse struts, of which there was a tier to each waling, were of whole timbers, 8 ft. apart in the length of the dam.

Simultaneously with the construction of these dams, the filling-in of the space behind the Temple Pier was going on, the line of the dam was being dredged, and the driving of the piles begun. The Temple Pier, 470 ft. in length, was irregular in outline, projecting in some parts upwards of 30 ft. in advance of the river wall, and the breadth across the foundation trench in the centre part was 57 ft. To avoid the necessity of having to use a large number of struts of such great length, this dam was strengthened by means of buttresses of piles, somewhat similar to those used in the coffer-dams constructed for the Grimsby Docks. These buttresses were placed at intervals of 20 ft., and were backed up by struts extending across the foundation of the pier. The scantlings of the timbers and the sizes of the bolts in this dam were similar to those in dams Nos. 1 and 2, the walings only being a little stouter, averaging 14 in. sq.

Before No. 3 dam was completed, No. 4 dam was begun, and was followed by Nos. 5 and 6. In these and all the dams, except No 3, the inner row of piles was placed so as to coincide with the riverward face of the concrete in the foundation trench. The piles, walings, and bolts of these dams were similar to those in dams Nos. 1, 2, and 3 ; but the shoring was of a different character. Across the breadth of the wall the struts were all horizontal, and abutted against walings of whole timbers, bolted to pairs of piles, driven into the solid ground behind the foundation of the wall. These coupled piles were placed at distances of 18 ft. apart from centre to centre, and were further supported by 3 back struts to each pair, 2 of which were horizontal and 1 raking. These struts abutted against piles driven into the slope of the filling material, and backed up with rubble stones. From the lower waling to the bottom of the trench, or to the solid ground, the space in all the dams was filled up with clay, or with a mixture of clay and gravel, to give further stability to the dam, and to assist the lower bolts to resist the pressure of the puddle. Sluices of 4$\frac{1}{2}$ in. elm plank, and having hinged flaps, were inserted in each dam, through the piles and puddle at the level of the lower waling. For dams Nos. 1 and 2, these sluices were 8 in. by 8 in., internal cross section. In the Temple Pier dam there were 2 sluices, 3 ft. high and 1 ft. wide, and for each of the other dams there was 1 sluice of similar section. In the Temple Pier dam, 2 iron cylinders, 8 ft. in diameter, were sunk to a depth of 4 ft. below the lowest level of the foundation, for pump-well, and in each of the other dams 1 such cylinder was sunk. The volume of water lifted out of the

Temple Pier dam varied from 620 gals. to 1,200 gals. a minute, according as a less or a greater area of the foundation was exposed ; but in all the other dams there was much less water to be pumped. As soon as the walls in any of the dams had been raised 6 ft. above low-water mark, no further pumping was needed, as the water which gathered when the tide was high was passed through the sluices at low water. Murray's chain pumps were used in all cases, and were found to be very efficacious. In coffer-dams there was usually a frequent settlement of the puddle, producing channels underneath the bolts and a consequent leakage. In such cases holes were bored with a 3 in. auger through the inner row of piles, immediately below the tie-bolts, and pellets of clay were driven through these into the puddle until the leakage was subdued. The quantities of material used in the dams were:—In the Temple Pier dam, timber 152 cubic ft., iron 285 lbs., and puddle 9 cubic yards per lineal foot of dam. In the other dams, timber 117 cubic ft., iron 202 lbs., and puddle 9 cubic yards per lineal foot of dam. The staging from which the dredging was executed and the piles driven, consumed 19.6 cubic ft. of timber and 13 lbs. of iron per lineal ft. Sissons & White's steam-pile drivers, and those of Appleby Brothers, were used, in addition to others wrought by manual labor. The cost of driving was a little under 4d. per foot of the pile when the ground was dredged, but was much higher where the ground was not dredged. The preparation of the piles cost $\frac{3}{8}$ths of a penny, and the fixing of the walings and shoring 4½d. per cubic ft., exclusive of the cost of fixing the tie-bolts.

In estimating the pressure to be resisted, and the requisite strength of the dam, the depth of water was taken at 22 ft., the piles were assumed to be 12 in. sq., and the struts 13 in. sq. The weight of a cubic foot of the dam was estimated to be 100 lbs., and the breaking strain of timber, measured by a load upon the middle of a bar 1 ft. long and 1 in. sq., was taken at 400 lbs. The pressure of the water was found to be 15,125 lbs., or 6.752 tons per lineal foot of dam. The momentum of the water tending to overthrow the dam was 110,916, whilst the momentum of the dam itself was 83,200. It also appeared that if the dam had been 9.23 ft. instead of 8 ft. in thickness it would, considered as a wall, have been, in relation to the pressure of the water, in a condition of equilibrium. The resistance of the piles to fracture at the ground line was calculated to be 47,127 lbs. in relation to a force acting at the centre of pressure of the water. If $\frac{1}{3}$ was taken as a safe load, the result was 15,709 lbs., to resist a pressure, as before stated, of 15,125 lbs. Disregarding these resistances, and reckoning the whole pressure of one bay to act upon each strut, the thrusts were, on the lower strut 222.82 tons, on the middle strut 77.5 tons, and on the upper strut 47.94 tons. But with every strut resisting an equal pressure the load on each would be 26.14 tons. For the pressure of the puddle on the tie-bolts the author had no satisfactory data, but he assumed it to be less than that of a similar section of water, and approximately the load upon the tie-bolts was calculated to be, at all events, less than the following amounts:—On each lower bolt 2½ in. in diameter, 85,250 lbs.; on each middle bolt, 2 in. in diameter, 54,875 lbs.; and on each upper bolt, 2 in in diameter, 37,625 lbs.

When the dams had served their purpose, it became necessary to clear them away, and before the completion of the whole series the removal of those first constructed had been begun. The piles in front of the ordinary wall were cut off at a level of 3 ft. under low-water mark, and those in front of the Temple Pier at a level of 7 ft. under low-water mark. The removal of the piles and puddle was effected in the following manner:—Upon the tops of the piles of each side of the dam half beams were fixed, and upon these, rails were laid so as to form a road upon which the steam cranes and dredging machines to be used in the removal of the puddle could travel, and upon which the pile-cutter could also be moved. These machines were successively placed in position, and the work was begun. For the first 15 ft. in depth the puddle was filled into skips, and hoisted by means of steam cranes. Below that depth it was dredged by the machines which had been used for excavating the trench. When the puddle had been cleared away to the requisite depth the pile-cutter followed and performed its part of the work. This machine consisted of a platform upon a

stout frame, resting upon four wheels, which travelled upon the rails before mentioned, and carrying a steam-engine with the requisite machinery for driving a circular saw, which was fixed at the lower end to an upright spindle, and adjusted to the proper level. The spindle was placed between the two rows of piles, and revolved in guides at the end of movable arms, so arranged that it would shift to either side of the dam by turning a handle, and by the same motion it could be pressed towards the pile which was being operated upon until it was severed by the saw. Two piles were usually cut off on each side before the machine required to be moved backwards on the rails. When the way was clear for the pile-cutter, and a sufficient length of dam dredged, 60 piles could be cut off in a day, but the excavators could not keep pace with the pile-cutter, and the average number of piles actually cut off did not exceed 36 daily. The machine was devised by Mr. Charles Murray, of Loman street, Southwark, and the author, but the motion which regulated the position of the spindle was the invention of Mr. Murray alone, and was patented by him. The total cost of the removal of the dams was £1 4s. per lineal foot, made up thus: clearing out puddle, 13s. 6d.; dredging outside of dam, 7s. 6d.; cutting off piles, 3s. per lineal foot.

THE STRENGTH OF CEMENTS.

From "The Engineer."

The use of Portland and Roman cements is so universal, the quantity which has been worked up is so large, the magnitude and importance of the structures in which they have been employed are so great, that it is assumed by most engineers, with some reason, that nothing remains to be said concerning the strength of the materials. If any engineer is bold enough to express a doubt on the subject, he is at once referred to Mr. Grant's celebrated paper ; and, if that will not suffice, to the experience of French engineers, and to the treatise of M. Leblanc in particular. Admitting the force of this argument as we do, we nevertheless do not hesitate to assert that there is one most important point connected with the strength of cements which has never yet received the smallest attention from engineers. Not a single writer on the subject has hitherto alluded to the elasticity of cement—in other words, to the "work" which any given mass of cement, Roman or Portland, is capable of performing before fracture ensues. It is only too commonly assumed that the best cement is that which resists per square inch of section the highest tensile strain. No account whatever is taken of the relative powers of different cements to endure sudden shocks or concussive forces. The cement tests made by Mr. Grant differ enormously in this particular from the iron and steel tests made by Mr. Kircaldy and others. In determining the structural value of any given sample of iron, Mr. Kircaldy, in deference to the opinions universally held by engineers, invariably takes the amount of stretch in the iron into consideration. A bar of iron is called brittle and good for nothing, even though it bears a very high tensile strength, if it breaks without previously undergoing considerable elongation, while a bar of iron which will give way with a comparatively small strain is considered very good indeed if, before it fails, it stretches some considerable percentage of its length. But no one who has tested cement ever thought of measuring the elongation which any sample evinced before it broke. It has been proved that the heavier Portland cement is—other things being equal—the greater is the strain required to pull a sample bar asunder, and we know that well made and well ground Portland cement, weighing 112 lbs. per bushel, is about the strongest cement in this sense which it is possible to use, Mr. Grant's experiments going to prove that it will stand a strain of from 600 lbs. to 719 lbs. upon 2.25 sq. in., or from 266 lbs. to 315 lbs. per sq. in. of section. But with this fact it may be said that our knowledge of the strength of cement begins and ends, and apart from questions concerning rapidity of setting price, and the method of mixing, and the proportion of sand to be used, it

is certain that our knowledge of the properties of cement for all practical purposes terminates. We are completely in the dark as to the suitability of the reverse of different cements for special and diverse purposes.

It will be urged that it is quite proper that mechanical engineers should know accurately how much "work" lies in any iron they employ, because iron is exposed to dynamical strains making large demands on the elasticity of the material; but that the amount of work residing in any sample of cement is of no importance whatever, because the strains to which it is exposed are statical, and, by their very nature, of such a kind that elasticity is a quality of no importance or value whatever in cement. It will also be said that no mortar or cement of any kind used by engineers possesses any elasticity whatever; but to argue in this way implies on the part of the arguer a greater or lesser—but, in any case, certain—ignorance of much that he ought as an engineer to know. It is simply impossible to draw a rigid line between static and dynamic strains. No manufacturer of cement can predicate with certainty that his cement will not be exposed to strains of such a character as will test its elasticity very considerably, and it is therefore unfair to argue that elasticity is not needed in cement. To use a ready illustration, we may point out that brick-work laid in cement is now extensively used in constructing foundations for heavy machinery. These foundations are kept in constant vibration, and exposed to dynamical strains varying extremely in direction and amount. Such foundations are constantly found to give way, cracking in all directions as though they were made of glass. It is evident to any one who has thought about the matter, that a little elasticity in the cement would prevent this cracking. But the cracking of an engine foundation is a small matter as compared with the repeated failure of large civil engineering works, such as breakwaters, docks, walls, etc., due indirectly, beyond question, to the want of elasticity—in other words, to the brittleness—of cement. As an illustration of the nature of strains to which works of this kind are submitted, we may cite the case of the splendid breakwater at Holyhead, now fast approaching completion. Under the full force of a heavy westerly gale rolling in a tremendous sea, the work rocks and vibrates to an extent which can only be realized by those who have stood on the wall inside the parapet at the time; and in direct confirmation of what we have said, we may state that mortar made of good Aberthaw lime has been found to sustain the shocks of the wind and the sea better than Portland cement of the best quality, apparently because the lime mortar possesses more elasticity than the cement. Other instances might be cited, all tending to prove that however suitable Portland cement is for such works as the main sewers of the metropolis, the piers of a bridge, or the Thames Embankment, it is not uniformly the best material that can be used for engine foundations, breakwaters, or other structures exposed to violent dynamical strains.

Whether it is or is not possible to impart elasticity to Portland cement remains to be seen. It is certain that unless it possesses some elasticity it is unlike all other known materials, but if it possesses some elasticity, different samples may possess more or less of the quality. Engineers have now to find out what kind of cement possesses most elasticity, and how far a high tensile strength and great elasticity are compatible with each other. In any case we can only use the words "great elasticity" as applied to cement, in the sense of comparing one cement with another. It may be found, however, that, just as with iron, so with cement, a moderate tensile strength may be accompanied by a measure of elasticity which will entitle an otherwise inferior cement to rank as one of the best known for certain purposes. We trust that some practical engineer will take this subject up, and handle it as Mr. Kircaldy has dealt with the strength of metals. Let bars of cement be cast, say 2 in. square and 10 ft. long; let these be put into a proper machine, and tested till they break by gradually applied loads. The stretch might be easily measured by fixing two small pins in the bar, say 9 ft. asunder, and allowing the short ends of two delicate levers kept apart by a light spring, and acting on suitable dial-plates, to abut against them. The elongation will, no doubt, be in all cases small; but Mr. Kircaldy would, we think, have no diffi-

culty in measuring a stretch of $\frac{1}{1000}$th of an inch in 9 ft. Shorter bars might also be submitted to impactive stress, and other bars again of varying section, material, and dimensions might be tested with advantage for transverse strength. The whole inquiry would prove eminently interesting and important, and as such we commend it to those engineers who have leisure and opportunity for carrying it out.

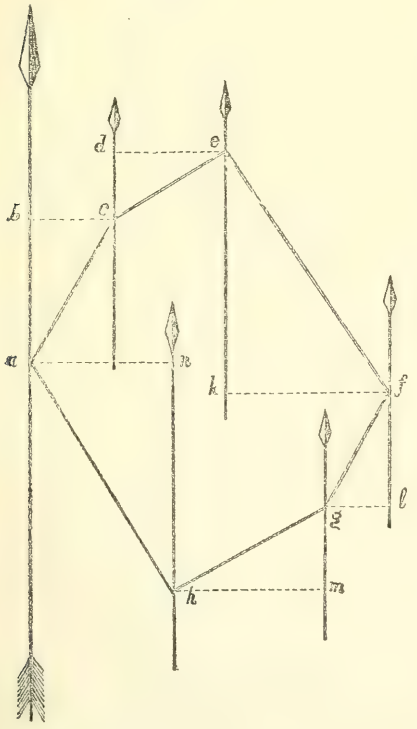
THE DETERMINATION OF AREAS BY THE METHOD OF PROJECTIONS.

By E. SHERMAN GOULD, C. E.

As it is believed that many surveyors employ the beautiful system of calculation by projections, commonly known as "Latitudes and Departures," without fully understanding its principles, the following simple investigation is offered:

Let us suppose the hexagon *a c e f g h* (Fig. 1) to represent a field, in which are

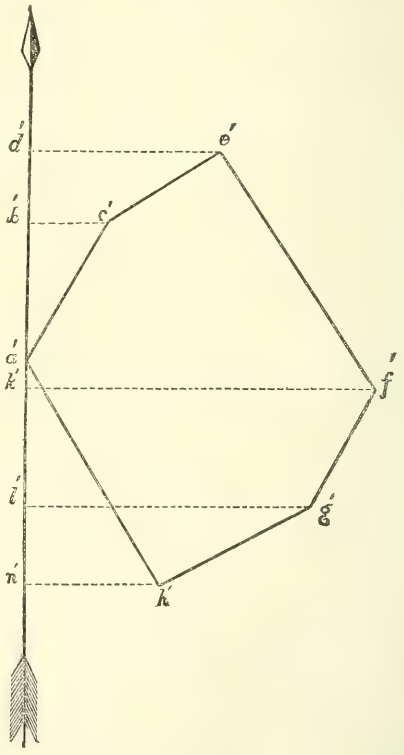
Fig. 1.



given the lengths of each side *ac, ce*, etc., and the angles which they make with a certain fixed straight line—in compass surveying, the magnetic meridian.

By a formula of trigonometry we can easily calculate the projections *ab, bc, cd, de*, etc. Now suppose the five easterly meridians shown in the figure to be moved bodily to the west till they coincide, in virtue of their parallelism, with the first, or most westerly meridian, the polygon remaining fixed. We would then have Figure 2.

Fig. 2.



It is evident that if we knew the numerical values of the new projections *a′b′, b′ c′, a′ d′, d′ e′*, etc., we could easily plot the figure and calculate its area, for it would only be necessary to draw a line representing the meridian, take a point *a′* upon it, and from that point lay off the abscissas, and then erect the ordinates from the proper points. The area would

be the entire polygon $d'\ e'\ f'\ g'\ h'\ n'$, less the two triangles $a'\ b'\ c'$ and $a'\ h'\ n'$, and the trapezoid $b'\ d'\ e'\ c'$.

But it is very easy to obtain these new projections from the first ones, by taking their algebraic sums (calling N and E bearings positive, and S and W negative) thus:

a′ b′ = a b.
a′ d′ = a b + d c.
a′ k′ = a′ d′ − e k.
a′ l′ = − a′ k′ − f l.
a′ n′ = − a′ l′ − g m or n h,
for the new abscissas, and
b′ c′ = b c.
d′ e′ = b c + de.
k′ f′ = d′ e′ + k f.
l′ g′ = k′ f′ − g l.
n′ h′ = l′ g′ − h m, or n a,
for the new ordinates.

The above are the principles on which the method of Latitudes and Departures are founded. For practical use, however, they have been reduced to a regular formula, which we will proceed to investigate by the light of what we have already established.

The rule teaches us that after writing down in one column the bearing and distance of each course, we should find their latitudes and departures from the traverse table, and with these form four other columns, headed respectively N, S, E, and W. This gives us the projections *ab*, *bc*, etc., of the first figure. We are also told that if the courses have been correctly taken and measured that the N. and S. latitudes, and the E. and W. departures, will be respectively equal. This is in virtue of the fact that if we start from a certain point and return to it, the positive and negative vertical projections of our path are equal, and together are equal to twice the vertical projection of the figure our path has made, the same being true of the projections on a plane perpendicular to the first. This is readily seen by reference to Figure 2.

Were the survey to be plotted as well as its area calculated, we might proceed at once, at this point, to plot it as already shown by the algebraic addition of its latitudes and departures, and then calculate its content directly from the co-ordinates used in plotting. But it frequently happens that only the area is required, and not the plot, and the rule then tells us to obtain the *double areas* by taking the *double departures* of the courses, multiply them by their respective latitudes, the products retaining the names of these latitudes; add the products of the same name together, subtract the less from the greater, and then divide by 2 for the area. We are told by the rule that these double departures are obtained by taking first, the departure of the course running from the most westerly point of the survey, which is the double departure of that course. then the double of this departure + the departure of the next course, for the double departure of that course, and so on to the last course, the double departure of which should be equal to the departure of that course.

Let us examine these successive steps. The most westerly station of the survey is taken, not from necessity, but for convenience, and because it obviates negative quantities in the column of double departures. This station is easily determined by an inspection of the columns of departures. Taking the west station leads us directly to Fig. 2. The object of the calculation is now to find successively the areas of the triangle $a'\ b'\ c'$, the trapezoids $b'\ d'\ e'\ c'$, $k'\ d'\ e'\ f'$, $k'\ l'\ g'\ f'$, and $l'\ n'\ h'\ g'$, and the triangle $a'\ n'\ h'$, and from the sum of the trapezoids forming the figure $d'\ e'\ f'\ g'\ h'\ n'$, to deduct the trapezoid $d'\ b'\ c'\ e'$, and the triangles $a'\ b'\ c'$ and $a'n'h'$.

These areas are easily found. That of the triangle $a'\ b'\ c'$ = half the product of $a'\ b' \times b'\ c'$. That of the trapezoid $d'\ b'\ c'\ e'$ = half the product of $d'\ b'$ by $b'\ c' + d'\ e'$, and so on. The first of these factors, viz. $a'\ b'$ and $b'\ d'$, we have already in the columns of latitudes, the second, viz. $b'\ c'$ and $(b'\ c' + d'\ e')$, we find, by the rule, under the name of *double departures*. (*Double multipliers* would be a more correct term.) This is readily seen, for $b'\ c'$ is the departure of the first course, and the sum of $b'\ c'$ and $d'\ e'$, the double departure of the second course, is twice the first double departure plus the departure of the second course. The double departure of the third course is the double departure of the second course, plus the departure of that course, plus the departure of the third course, as will be seen by the figure. And so on, calling East departures positive and West negative, and adding them algebraically. The *double* areas are taken to avoid the division by 2 of each product, which would lead to fractions.

It will be seen from Figure 2 that the lesser areas are always of the name of the latitude of the initial course.

PILE FOUNDATIONS.*

By RICHARD DELAFIELD, BVT. MAJ.-GEN.

The dry dock at the Brooklyn Navy Yard, New York, was commenced in 1841 and completed in 1851. It contains 13,837 cubic yards of masonry, resting upon 38,532 cubic feet of pile timber.

The soil was found to be chiefly vegetable decomposition to the depth of 10 ft., and below this almost impalpable quicksand containing a large proportion of mica. When confined, and not mixed with water, it is very firm and unyielding, presenting a strong resistance to penetration. When saturated with water it becomes a *semi-fluid*, and moved by the slightest current of water passing over or through it. Small veins of coarse sand were also occasionally encountered, through which flowed springs of fresh water. Borings were made to the depth of 80 ft., and brought up sand and clay and fresh water. There is but a small proportion of clay in any part of the foundation. The borings extended 40 ft. below the foundation of the dock.

The foundations for the superstructure of this dry dock were placed 37 feet below mean tide and 42 feet below the surface of the ground. Black mica overlaid the quicksand under the coffer-dam. Under and in this coffer-dam 3,504 piles were driven, averaging 39 ft. in length by 15 in. square.

The earth above low water was removed before the coffer-dam was formed, and about 10 ft. in depth was removed by dredging. The *semi-fluid* state in which the material was found after the water had been pumped out of the pit, was very difficult to remove. It was so fluid as to require tubs for its removal. Bottom springs of fresh water were found in about 6 ft. of the required depth of the foundations. The largest discharged 10 gals. per minute. When flowing from a level of 26 ft. below low water it discharged 38 gals. per minute, containing 27 oz. of sand; at a level of 22 ft., it discharged 33 gals. per minute, containing 17 oz. of sand; at a level of 17 ft., it discharged 10 gals. per minute, unmixed with sand.

These springs presented great difficulties in laying the foundations from the flowing of the water, which as it came up brought large quantities of sand, which if it continued to flow, would soon have endangered the surrounding works. The pressure of the water was so great as to raise the foundation, however heavily it could be loaded.

The settling of the piles supporting the pump well, was the first evidence of undermining from one of these springs. The site of the well was changed, but the spring followed and compelled another change of the well.

This spring was driven out of the old well by driving *piles* until it was filled up, but it immediately burst up among the *foundation piles* of the dock near by. In a single day it made a cavity in which a pole was run down 20 ft. below the foundation timbers. 150 cubic ft. of stone were thrown into this hole, which settled 10 ft. during the night, and 50 cubic ft. more were thrown in the following day, which drove the spring to another place, where it undermined and burst up through a bed of concrete 2 ft. thick. This new cavity was repeatedly filled with concrete, leaving a tube for the water to flow through; but in a few days it burst up through a heavy body of concrete in a place 14 ft. distant, where it soon undermined the concrete, and even the foundation *piles*, which settled from 1 to 8 in. although 33 ft. long, and driven by a hammer of 2,200 lbs. falling 35 ft. at the last blow, with an average of 76 blows to each pile, the last blow not moving the pile $\frac{1}{2}$ an inch. It was then determined to drive as many additional piles into the space by means of followers to force those already driven as deep as possible.

The old concrete was then removed to a depth of 20 in. below the top of the piles. An area of about 1,000 sq. ft. around the spring was then planked, on which a floor of brick was laid in dry cement, and on that another layer of brick set in mortar. The space was next filled with concrete, and the foundations completed over all. Several vent holes were left through the floor and foundations. After a few days when the cement had

* From a Memoir on Foundations in Compressible Soils, with experimental tests of Pile Driving.

well set, the spring was forced up to a level of about 10 ft. above the former outlet, at which it flowed clear without sand.

Two other of these springs were closed by freezing in 1848, and forced up in one case 800, and in the other 1,200 sq. ft. of the foundations. This took place between the lower timbers and the planking, *lifting also the first course of the stone floor*, which was from 12 to 15 in. thick.

The whole number of bearing piles in the foundation is 6,549. They are chiefly round spruce timber 25 to 40 ft. long, averaging 14 in. diameter at the head. The *average length* of all the *piles* driven was 32 ft. 7 in. The piles were originally driven 3 *ft. from centres*. Afterwards as many piles were driven as could be forced into the earth. Whenever a hammer of 2,000 lbs. weight, falling 35 ft., drove the pile for the last few blows, exceeding 3 in. per blow, another and larger pile was driven along side.

With the exception of 541, all these piles were driven by hammers from 2,000 to 4,500 lbs. each, falling from 35 to 40 ft. The average number of blows per pile was 151 with the small hammers, and 50 blows only per pile with the large hammers. The 541 piles were driven with a Nasmyth steam-pile engine.

A trial round pile of 20 in. diameter at the butt, and 14 in. at the small end, of 49 ft. in length, was driven by a 2,024 lbs. hammer, falling finally 35 ft.; 45 ft. below the foundations. The first 100 blows the hammer fell but a few inches; the next 260 blows drove the pile 30 in. in 46 min.; the next 260 blows drove $\frac{1}{2}$ in. to $1\frac{1}{2}$ in. per blow for 60 min.; the next 110 blows averaged $1\frac{1}{4}$ in. per blow for 60 min., the hammer falling the last blow 34 ft.

This trial pile subsequently received 200 blows through the medium of a follower which drove it an average of $\frac{1}{2}$ an inch to each blow.

Another trial pile was driven 43 ft. by a Nasmyth steam-pile driver, and then another pile 15 ft. long, driven on top of the first, making a total penetration in the earth of 57 ft.

The first pile driven 42 ft. by 37 was blows in 7 minutes as follows:

4 blows	4	inches each.
8 "	$3\frac{1}{2}$	"
22 "	3	"
25 "	2	"
40 blows	$1\frac{1}{2}$	inches each.
56 "	$1\frac{1}{2}$	"
32 "	$1\frac{1}{4}$	"
64 "	$1\frac{1}{3}$	"
73 "	1	"
48 "	$\frac{1}{2}$	"

The second pile was driven 15 ft. by 2,400 blows in 43 minutes as follows:

33 blows,	$\frac{3}{8}$	of an inch each blow.		
73 "	$\frac{1}{4}$	"	"	
100 "	$\frac{1}{8}$	"	"	
800 "	drove it altogether		88 in.	
300 "	"	"	24 "	
300 "	"	"	12 "	
450 "	"	"	11 "	and the last.
350 "	"	"	$5\frac{1}{2}$ "	

The movement of these piles indicated the continuance of the same material to the depth which they reached.

The foundation was mostly laid as follows: The excavation being completed to the proper depth, and piles cut off to a uniform level, 2 ft. in thickness of *concrete* was *rammed between the bearing piles*. These piles were then capped with 12 and 14-in. yellow pine timber, laid transversely with the axis of the dock, and *treenailed* to each pile. The concrete was then raised to the top of these timbers, and a light flooring of 3-in. yellow pine plank was laid upon and spiked thereon. Another course of similar timber was then placed upon this floor, breaking joints with those below, to which they were treenailed. The intervals were next filled with concrete, and another floor of 3-in. plank spiked down, which completed the foundation.

The amount of work done by the heavy Nasmyth hammers was at least $\frac{1}{3}$ greater than that done by those whose hammers were only half the weight. This Nasmyth hammer of 4,500 lbs. was worked with very short rapid blows, raised a height equal only to the stroke of the engine.

The support of this foundation is derived mainly from the adhesion of the material into which the piles were driven and slightly from their sectional area.

It was ascertained that it required a weight of 125 tons to draw up one of these piles, or rather to start or put it in motion, when driven 33 ft. to the point of ultimate resistance, with a ram of 1 ton falling 30 ft. at the last blow. The piles averaged 12 in. in diameter in the middle, making at least a support of 100 tons per square foot of foundation.

PILE FOUNDATIONS AT THE PHILADELPHIA NAVY YARD.

At the site of the dock of the Philadelphia navy yard, commenced in 1849, the first stratum of soil is a mud of rich loam extending from a little above low water level, declining towards the bottom of the river, which is of a clean gravel, to the depth of about 24 ft. below ordinary low tide, and evidently the deposit through a long period of years of the earthy matter held in suspension by the waters of the Delaware river, upon a stratum of sand and gravel forming the bed of the river. The sand and gravel are not more than from 4 to 7 ft. in thickness, before those substances become mingled with paving stones, large boulders, and to some extent with clay, forming a species of hard pan, to which all the piles used in the construction of the foundations of the work were driven. The object of the foundation of the basin of the dock was to give support to its bottom, and to secure its outer edge against the action of the current of the river. As the excavation was completed, piles were driven 4 ft. apart from centres in rows from one end of the space to the other. An extra row was driven under the line of the walls of the three sides of the basin. A space was then formed by drawing a line of sheet piling 8 ft. from the inner line of piles of the coffer-dam. Two extra rows of piles were driven within this space, which was then filled with concrete to within 2 ft. of the floor of the basin. The piles thus driven were cut off to the same level, capped with timbers 1 ft. square, and the spaces between these capping timbers filled with earth and concrete. (Stewart's "Dry Docks of the U. S.")

PILE FOUNDATIONS AT THE PENSACOLA NAVY YARD.

The dock at the Pensacola navy yard was built in 1851 and 1852. The soil of this locality is clean white sand, to the depth of about 40 ft., resting upon a bed of soft clay. The sand is so open and porous that a cubic foot of it, when saturated, contains 6 quarts of water.

A space of 140 ft. wide by 380 ft. long was inclosed by driving yellow pine piles, 12 in. square, to the depth of about 20 ft. into the sand, placed in contact with each other, for forming a coffer dam. Within this space, secured by other means against filtration, the sand was excavated to a depth of 14 ft. below tide.

After a section of the pit had been excavated to the level of the foundations, the bearing piles were driven in rows 4 ft. apart, and 4 ft. from centres in each row until a ram of 2,200 lbs., falling 30 ft., could not move them more than $\frac{1}{2}$ an inch. *Upon* the transverse rows of piles cap timbers, 12 in. square, were placed, and the space between the timbers filled with sand. The timbers were then covered with 5-in. plank, spiked to the caps, and the whole floor caulked with wedges. On this floor the masonry of the basin was commenced. This foundation was tested and found satisfactory. The experimental tests showed that a single foundation pile, as a *fulcrum*, sustained nearly 39 tons without settlement; and it required 41 tons strain to draw a pile that had been driven 16 ft. into the sand.

The railroad bridge at Havre-de-Grace, on the Susquehanna river, was commenced in October, 1862, and finished in November, 1866.

The foundations of the piers of this bridge are referred to as examples of piles driven in the compressible bed of the river, supporting an iron caisson on a grillage of timber resting on the piles, and a caisson lowered to solid rock through 15 ft. of compressible soil.

In 1863 piles were driven and sawed off 40 feet below the surface of the water for the foundation of pier No. 3; a platform or grillage of timber, strongly ironed, upon which the pier was to rest, was constructed near the site of the work and floated over the site of the foundation under which the piles had been driven. This platform was placed between two substantial construction piers of timber; lowering screws, 6 in number, of $3\frac{1}{2}$ in. diameter, were attached by hooks to the platform; and to the construction piers a section of an iron caisson was constructed, resting upon the wooden platform thus suspended. The masonry was then built within the caisson, lowered by means of the screws, as it approached the top of the section, when a second section of the iron caisson was added, built within and lowered by the screws in like manner as the preceding, and thus continued until the grillage or wooden platform rested upon the heads of the piles.

Another pier (No. 7) was founded on

the rocky bed of the river underlying the compressible bed of the stream for a depth of 15 ft. This latter had been displaced in several places by the spring freshets of 1865, rendering piling impracticable; all the earth was, in consequence, removed down to the surface of the rock. At the site of this pier the rock bed was 18 ft. below the original undisturbed bed of the river. To remove this earth a wrought-iron foundation caisson, averaging 8 ft. in height and about 50 ft. by 20 ft. square, was lowered so as to enclose the site of the pier. This was gradually depressed to the rock by removing the earth within it by means mainly of powerful pumps, aided by the constant exertions of skilled divers. The masonry was then laid within the tank upon the solid rock, and being brought to a level some feet below the top of the foundation caisson, the caisson of the pier resting upon the platform of timber was lowered and built upon. Tne foundation of this pier was 36 ft. below low water.

RESISTANCE OF PILES TO PRESSURE.—FORT RICHMOND, STATEN ISLAND, NEW YORK.

The soil of part of the foundations of Fort Richmond, now Fort Wadsworth, on being excavated to low-water level, was found to be very compressible, with springs discharging large quantities of water. The scarps and counterscarp of the southern half of the land front and face of the adjacent bastion of the water front were situated on such a soil, resembling that of the dry-dock at Brooklyn. The weight to be sustained was a granite casemated battery of four tiers of 8 and 10-inch guns, with the shot, shell, and other munitions therefor. The scarps, piers, and arches, are all of granite.

Piles were in this case resorted to, and no settlement has since been noticed. The work was commenced in 1856, and finished to receive its armament in 1861. The piles were 30 ft. long, 12 in. square at the head, and not less than 10 in. at the small end. They were driven by a hammer of 1,800 lbs. weight, with blows in quick succession, the last blow of the hammer being from a height of 45 ft. They were cut off level with the surface of the ground, and capped with large flat stone, covering the heads of from 3 to 5 piles—the joints being filled with concrete, well rammed. A second layer of large flat stone, breaking joint with the first, on which the masonry of the granite scarp was commenced. It will be noticed that there was no timber grillage covering the heads of these piles.

RESISTANCE OF PILES TO PRESSURE.—EXPERIMENTAL TESTS AT PENSACOLA.

In 1851 a series of experiments were made under the direction of a special board of officers, on the resistance, etc, of the piles driven for the foundations of the dock of the navy yard at Pensacola. A pile that had been driven six days, surrounded by other piles 4 ft. distant from centres, of 30 ft. in length, averaging 13 in. diameter about the middle of its length, round, with bark on, was first selected for these experiments. The average depth of the pile in compact sand was 15 ft., driven by a hammer of 4,087 lbs. and 69 blows, at the rate of 2½ blows per minute.

The first experiment, made on the 17th of May, was the application of a power (by pressure or loading) of 23,850 lbs. to a pile for 5 minutes, which it bore without moving. The second experiment was by applying a power of 20,000 lbs. to another pile; a third pile was subjected to the same strain for 5 minutes; and a fourth pile resisted the same power for 5 minutes. There was then applied to this last pile 31,360 lbs. (14 tons) for several minutes. Three other piles were subsequently tried, and each resisted 22,400 lbs. (10 tons) pressure for 5 minutes.

The next test was by pulling up the piles, beginning with 22,400 lbs. applied to the pile No. 4, before noted, increasing the power 1 ton every 2 minutes—that is, after 10 tons had been applied for 2 minutes; then 11 tons were applied for 2 minutes; then 12 tons, and so, until 15 tons, or 33,600 lbs. pressure, had been tried, when a hook of the steelyards broke. Three days afterwards the experiment was resumed, beginning with 10 tons, gradually adding ton by ton, until there was 31½ tons of upward strain acting upon the pile. This experiment lasted 1 hour and 40 minutes, during which time the power upon the pile was constant.

There was afterwards a gradual increase of power to 39 tons without moving the pile. It then resisted 40 *tons* for half a minute, when it *began to rise* slowly. 41 *tons* were then applied for 1⅔ min.; then 41½ tons for half a minute, the pile mean-

while moving upwards at the rate of $\frac{1}{12}$ *of an inch per minute.* The tests of 40, 41, and 41½ tons, occupied half an hour, during which, the strain being constant, the pile was moved 2½ in.

It was then subjected to a strain of 30 tons for 18 hours, and was not moved by it. After which, by adding from 2 to 7 tons, the pile was moved, in 1 hour, 3 in.; and, after it had moved upwards about 6 in., a power of 25 tons was allowed to remain on it for 2 *days* and did not move it. The pile was then withdrawn from the sand. Its extreme length was 29 ft. The length of the part which had been in sand was 16 ft., including the sharpened end of 2 ft. in length; 1 ft. in depth about this pile was *loose sand,* which had been once excavated and fallen back. The average diameter of the part in the sand was 13½ in., including the bark. The bark remained on the entire pile, except on 3½ ft. on its pointed end. This pile weighed 1,632 lbs.

A single pile used as a fulcrum for the lever sustained at the most, during the experiment, $38\frac{96}{100}$ tons weight without settlement. Experiments showed that piles which one day penetrated $\frac{6}{10}$ of an inch per blow of a 4,087 lbs. hammer, falling 10 ft., was found to penetrate $\frac{1}{8}$, $\frac{1}{2}$, and $\frac{6}{10}$ of an inch, by three similar and successive blows applied the following day—the three blows being given in *one minute.* If the pile is allowed to remain undisturbed a short time, the power to move it afterwards is greatly increased. (Stewart's "Dry Docks of the United States.")

McALPINE AND SANDERS' FORMULA FOR A BEARING WEIGHT OF PILES.

The formula deduced by the engineer, Mr. McAlpine, from his labors at the Brooklyn Navy Yard, applicable to rams of 1,000 lbs. to 3,000 lbs., falling from 20 to 30 feet, was

$$\chi = 80\ (W + .0228\sqrt{F-1.})$$

In which χ was the supporting power of a pile driven by the ram W, falling a distance F; χ and W being in tons, and F in feet—and that not more than ⅓ of the result given by this experience should be borne or relied upon for any piles.

Major Sanders' formula, deduced from his experience in driving piles at Fort Delaware, with a ram of 3,500 lbs., falling 3½ feet, driving a pile 4′.2, is

$$\frac{R}{3500+42}+\frac{h}{8}+\frac{d}{4'.2} = \frac{35000}{8} = 4{,}375 \text{ lbs.},$$

the weight which the pile would bear with safety. (See Stewart's "Dry Docks of the United States," and "Engineer and Scientific Journal" for 1867.

FOUNDATIONS OF FORT MONTGOMERY ON PILES AND GRILLAGE.

The foundations of Fort Montgomery, on Lake Champlain, near the latitude of 45 deg., was commenced in 1844, and the driving of 4,383 piles was finished in 1846. These piles were capped with a timber grillage in 1848. *Each pile* was calculated to sustain a weight of 7 cubic yards of masonry and 1¼ yards of earth, or a total weight of 34,125 lbs., or 15.27 tons.

The piles were driven about 3 ft. apart. The grillage is in two courses, the lower one, 1 ft. 3 in. wide and 12 in. thick, is notched down 4 in. on the heads of the piles, and pinned thereto. The upper course at right angles to the lower one is 12 in. square across the piles, and 12 in. × 8 in. between them, the 12 in. × 12 in. being notched 4 in. down on the lower course, thus giving a level floor for the masonry. The length of the piles, after being driven and cut off, was from 29 to 33 ft. The fall of the hammer at the last blow was from 35 ft. 8 in. to 36 ft. The diameter of the piles was from 12 to 16 in. at the butt, and 9¼ to 14 in. at the smaller end. The last penetrations were from 2½ to 6½ in. These facts apply to 39 piles, given as examples and illustrations of the whole. The hammer weighed 1,630 lbs. The weight of the spruce piles was about 39⅕ lbs. to the cubic foot. The pile weighed was rather more dry than the average. At least 40 lbs. to the cubic foot would be a proper average.

The compressibility of the soil into which these piles were driven was about one-ninth of its entire bulk.

COLONEL MASON'S FORMULA FOR BEARING WEIGHT OF PILES.

Colonel Mason deduces the following formula from an investigation of the value of this foundation, or the amount of weight with which each pile may be loaded: Let h be the height of the fall of the hammer at the last blow, s the distance to which the pile penetrates at the last blow, 1,630 lbs. the weight of the

hammer, 960 lbs., the weight of a pile 24 cubic feet, and joint weight of pile and hammer 2,590 lbs.; g the force of gravity ($32'\frac{1}{6}$,) or the velocity that gravity will generate in a second of time, and $\sqrt{2gh}$ = velocity of hammer as it strikes the pile, $\frac{h}{s}$ is $\frac{36'}{3''.75} = 115.2$, and we have for the value of the retarding force $1{,}630 \times \frac{1}{2}\frac{6}{5}\frac{3}{9}\frac{0}{0} \times 115.2 = 118{,}175$ lbs., or 52.75 tons. Each pile was actually loaded with and supported the average weight of 28,575 lbs., or 12.75 tons, besides its own weight (960) lbs.) and that of the grillage, or about $\frac{1}{4}$ of that which the calculated force of resistance is capable of holding in equilibrio.

In the above case the *velocity* of the hammer at the moment of impact will be $\sqrt{2 \times 36 \times 32\frac{1}{6}} = 48.125$ ft. per second, and the velocity of the joint *mass* of hammer and pile will be $48.12_{\frac{h}{g}} \times \frac{1}{2}\frac{6}{5}\frac{3}{9}\frac{0}{0} = 30.3$ ft. per second $= V'$, and the retarding force

$$\frac{V'^2}{2s} \text{ will be } \frac{30'.3}{7''.5} = \frac{918'}{7''.5} = 1{,}468,$$

the velocity that the retarding force is capable of destroying in a second of time on the joint mass of the pile and hammer is then 1,468 ft. But gravity is capable of generating on that mass a velocity of $32\frac{1}{6}$ ft.; dividing 1,468 by $32\frac{1}{6}$ we have 45.63 as the ratio between the *retarding force* and the *force of gravity*. That is, the *retarding force* is capable of holding *in equilibrio* 45.63 *times* the joint weight of the *pile and hammer*, or 2,590 pounds $\times$ 45.63=118,181 pounds. This is within 6 lbs. of the previous result. The time (t) in this case will be

$$t = \frac{2s}{V'} = \frac{7''.5}{30'.3} = \frac{2}{97} \text{ of a second.}$$

The same result may be obtained by dividing the velocity destroyed, viz., 30'.3, by the velocity the force is capable of destroying in a second of time, viz., 1,468; or $\frac{30.3}{1468} = \frac{2}{97}$ on the supposition of of a constant force during the short period that it takes to destroy the motion of the pile, instead of a retarding force. Colonel Mason concludes his memoir with the deduction that Fort Montgomery experience is in favor of a coefficient of stability of $3\frac{6}{10}$ when applied to the calculation under the supposition of a constant force, although it in reality, as a general rule, decreases by very small decrements towards the terminal penetration; and hence, taking this coefficient as a constant, is erring on the safe side.*

Major Sanders' experiments at Fort Delaware were made with a view of deducing a rule for foundation on compressible soils, without any firm substratum lying within reach of piles, for calculating what weight each pile would bear with safety, by comparing the distance it was sunk at the last blow, with the force of the blow, it being understood that the pile has been driven to such an extent that for a number of blows the penetration has been uniform for equal blows. To ascertain such a rule two sets of piles of four each were driven, and a platform built on their heads; they were then loaded with blocks of stone piled regularly on the platform; and at regular intervals of time the amount of subsidence caused by the weight, which was periodically augmented, was noticed. These piles were *not driven* through the alluvial; their points were about 20 ft. from the sandy sub-soil, so that their stability was due to the accumulated and constantly increasing resistance of the same medium.

In one experiment the four piles were driven to a depth of about 24 ft. each, with a pile driver that struck 34 blows in a minute, with a ram of 2,000 lbs., and a uniform fall of 6 ft. An artesian well sunk on this island in 1834 found mud continuously to a depth of 46 ft. below low-water mark, then 20 ft. of sand, then 30 ft. of coarse sand containing shells. It then entered and penetrated for 47 ft. a bed of marl, which contained boulders. At the penetration of 24 ft., each of the blows of the ram drove them about an inch, or exactly $\frac{1}{74}$ of the fall of the ram. The weight placed on them at first was about 60,700 lbs., (or about $\frac{1}{9}$ of the product of the friction and the weight of the ram.) This weight caused a subsidence in six months of $\frac{6}{3\frac{1}{2}}$ of an in., when 15,000 lbs. were added without increasing the subsidence. Upon again increasing the weight till it reached 94,000 lbs., (the ratio corresponding to which was $\frac{1}{6}$,) the subsidence began again, and in a month had attained $\frac{8}{3\frac{1}{2}}$ of an in. when it ceased, or at least made no progress during the

* For a more minute detail of Colonel Mason's investigation of this subject see papers on Practical Engineering No. 5, by Colonel J. L. Mason, Corps of Engineers, U. S. Army, 1850.

ensuing three months. The next addition to the weight brought it to 107,500 lbs., and the ratio to about $\frac{1}{5}$, and in a month increased the subsidence to $\frac{9}{32}$ of an in. The next addition raised the weight to 121,800 lbs., and the ratio to 1:4.6. This weight remained upon the piles *without alteration* till three years and five months had elapsed. In the first eight months it had caused the subsidence to increase from $\frac{9}{32}$ to $\frac{16}{32}$ of an in. ; and this subsidence did not increase during the remaining two years and nine months of the period. During the ensuing seven months the weight was successively increased to 134,000, 147,000, 160,000, 174,000, and finally to 189,500 lbs. (or 84.59 tons); the ratios corresponding to which were respectively 1:4.19, 1:3.81, 1:3.52, 1:3.23, and 1:2.969. Until the last weight was put on no additional subsidence was caused by the increased pressure. It will be seen that the weight, answering to the ratio of 1:4.6 above mentioned, remained upheld 3 years and 4 months without the slightest variation in the subsidence of the piles, although it was repeatedly added to, and the whole system jarred in doing so during that period. But upon laying of the last load of stone the subsidence again began, and at the end of the ensuing period of 1 year and 5 months had arrived at $\frac{26}{32}$ of an in. This subsidence did not go on uniformly, but by steps at a time. It seemed to be ceasing at the end of the period, judging from the facts that the intervals of rest were longer and the successive subsidence less towards that date, viz., April 12, 1856. The next time that the observations were made on the levels of the pile heads was on the 24th of April, 1860. The subsidence had then arrived at an average of 1 *inch* within an appreciable fraction, showing an increase in 5 years and 5 months of $\frac{6}{32}$ of an in. It is probable that this subsidence took place within the 2 or 3 years that followed the date of April 12, 1856, and that the piles have remained immovable for the last 2 years at least.

The whole period over which this experiment extended was (May, 1860,) about $9\frac{1}{2}$ years. The conclusions that may be derived from it are obvious; that the subsidence had ceased may be safely assumed. It follows that a building on piles, driven in soils exactly of the nature of that in which these experimental piles were placed, will be safe if we do not load them with a greater weight than the *third part of the quotient arising from dividing the product of the weight of the ram and the distance it falls, by the distance the pile is sunk by the last blow.* The coefficient was, however, fixed by Major Sanders for safety at $\frac{1}{8}$. Conversely, having given the weight of the superstructure, we can by the same rule ascertain the minimum number of piles that will sustain it if driven to a fixed depth, or the depth to which an approximately fixed number of piles must be driven to effect the same purpose.

There were two experiments of the kind we have described made at Fort Delaware. The second one continued $3\frac{1}{2}$ years, had similar results, and was equally regarded in the determination of the coefficient used in the rule.

From other experiments made during the same period, Major Sanders ascertained the relation between the living force of the ram and the distance the pile is sunk for *different falls* by a series of experiments on 64 piles, which received 1,900 blows from a ram of 800 lbs. It was found that when the fall was less than 3 ft. the useful effect was extremely small; that it gained in a rapidly increasing ratio as the fall was augmented, a foot at the time to 5 ft.; and that at this point the ratio of useful effect to the force expended is at its maximum, and that the piles are driven to distances proportional to the blow; or, in other words, that there is nothing gained by increasing the fall beyond 5 ft.; for example, 2 blows of 5 ft. will sink a pile as much as 1 blow of 10 ft.; 3 blows as much 1 of 15 ft.; 4 blows of 5 ft. as much as 1 of 20 ft. It was also found that if the 5 ft. blows followed each other in rapid succession the useful effect was rather greater than if the interval employed in common hand-power machines for hoisting the ram was allowed to elapse.

From 1833 to 1838 11,000 piles, of 45 ft. in length, 12 in. sq. at the head, and not less than 10 in. diameter at the small end, were driven for the foundations of Fort Delaware, under the superintendence of Captain Delafield, of the Corps of Engineers, with a hammer of 1,800 lbs. by blows in quick succession with steam power, the maximum fall of the hammer being 45 ft. Since 1850 4,500 additional

piles were driven under Major Sanders' superintendence, from which experience he has drawn the preceding deductions. 6,600 of these piles are under the scarps and casemates of the present work. (See Lieut. Morton's Life and Services of Major John Sanders, of the Corps of Engineers, 1861.)

In 1848 the excavations for the foundations of the work existing at this time (1868) were commenced and completed in 1849, and the piling by Major Sanders, heretofore referred to, was finished in 1851. By 1853 2,000 tons of masonry had been laid on these piled foundations, and in 1859 the walls, arches, and other masonry were finished.

Three bench marks were established in 1854, reference to which was made in 1859, when it was found the masonry had not settled in any part.

From 1859 to October, 1866, the settlement on reference to the above bench marks was 4 in. at the maximum point, and 2.65 in. at the minimum, and a mean settlement for all the observed points of 3.19. No crack was perceptible in any part of the work in 1866 or in 1868.

RESISTANCE OF PILES DRIVEN AT THE S. W. PASS OF THE MISSISSIPPI RIVER, ON STAKE ISLAND.

Stake Island consists of 2 mud lumps, forming its northwest and southeast extremities about 500 yards apart. At both points the ground is high, of the character of other mud lumps.

The space between the two mud lumps is much lower, presenting the same general features and vegetation as the land on either side of the river. The ground between these two lumps is about as solid as anywhere higher up on the river between the passes and the city. The experimental pile driving commenced on the 19th November, 1867.

Pile No. 1 was 30 ft. long. After 12 blows the *head* of the pile within 1 ft. 6 in. of the ground was rent to pieces. The head of the pile was square timber, 11 in. at the upper end, and 10 in. diameter at the lower end, banded with ½-in. iron 3½ in. wide. Outside diameter 9½ in. The broken part of the pile was then cut off, and a piece 15 ft. long set on top of it. 17 more blows were then given when the pile gave way, tearing the head completely off. The total depth obtained by these 29 blows was 41 ft. 11 in., being driven to low-water mark, and level with the lowest soil.

Pile No. 2, after 12 blows, was broken at the head, cut off, and a piece of 17 ft. in length set upon it. 23 additional blows drove the pile down to 45 ft. 1 in. below the surface of the ground.

Pile No. 3, 30 ft. long. After 11 blows the head of the pile was badly rent 4 ft. 6 in. above ground. 3 ft. 9 in. were cut off, and a piece of 18 ft. 6 in. set on, when with 9 blows the head gave way. 5 ft. 1 in. was then cut off, and with 7 more blows the pile was 35 ft. 8 in. below the surface.

Pile No. 4 was the same size as the previous piles. After 10 blows the head was 1 ft. 8 in. above ground, and was then cut off, and 16 ft. set on; 27 more blows were given, and 1 ft. 9 in. cut off; when a piece of 16 ft. was set on, and after 13 more blows 4 ft. were cut off, leaving the pile 54 ft. 2 in. in the ground and 5 in. above.

The maximum fall of the hammer was 28 ft. The size of the hammer, of cast iron, was about 2 ft. 5 in. high, 1 ft. 8 in. wide, and 1 ft. 1 in. thick.

The penetrations of these piles are as follows.

No. 1, with the first blow falling				5′ 9″,	was 6′ 3″.
" 2,	"	"	"	1′ 6″,	" 7′ 8″.
" 3,	"	"	"	4′ 3″,	" 9′ 1″.
" 4,	"	"	"	3′ 6″,	" 11′ 4″.
No. 1, with the *last blow* falling				28′ 5″,	was 10 in.
" 2,	"	"	"	28′ 7″,	" 22 in.
" 3,	"	"	"	26′ 6″,	" 9 in.
" 4,	"	"	"	25′ 5″,	" 14 in.

(See Bonzalo to Gen. McAlister, 9th January, 1868.)

In March, April, and May, 1868, 45 piles, of 50 to 60 ft. in length, were driven under the direction of General McAlester, at St. Joseph's Island, in the same alluvial soil as deposited from the Mississippi river. The same remarkable uniformity of penetration, by the successive blows, was developed as at Stake Island.

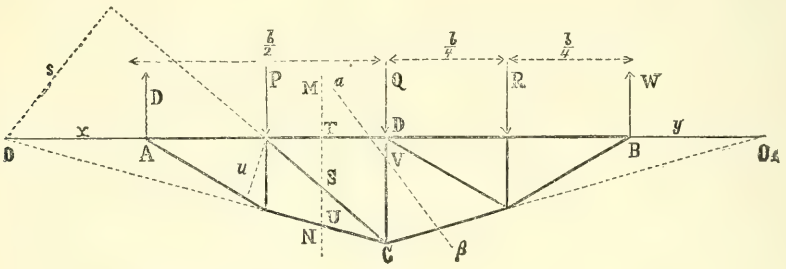
RAILWAYS IN THE ARGENTINE REPUBLIC.—The Senate of the Congress of the Argentine Republic has passed a bill for the construction of a line through the heart of the Gran Chaco. The line would run from Santa Fe to Santiago del Estero, and would open a new port on the Parana for the Upper Provinces. The distance between the two points is about 400 miles.

CALULATIONS OF STRAINS IN TRUSSES.—No. II.

The advantage of the method described in the last number consists in the fact that the strain in a given piece can be immediately obtained by a single equation. Another advantage is that the same equation determines what distribution of load gives a maximum or a minimum strain in a given piece. In order to determine the maximum strain, all loads tending to diminish the strain are cancelled from the equation; and, conversely, to find the minimum (*i. e.*, the greatest *negative* maximum), the loads that increase the tension in the given piece are cancelled.

In most bridge trusses, and in many roof trusses, it is of great importance to investigate the strains due to variations in load, since a full load does not generally put the maximum strain upon a given piece.

Fig. 1.



To determine the strain S in the construction represented in the figure (1) we pass through it the section M N, and take moments about O. This gives the equation of moments,

$$S s - D x + P\left(x + \frac{l}{4}\right) = 0.$$

or putting for D its value

$$\tfrac{3}{4}P + \frac{Q}{2} + \frac{R}{4},$$

$$S = \frac{-P\left(\frac{x}{4} + \frac{l}{4}\right) + \frac{Q}{2}\cdot x + \frac{R}{4}\cdot x}{S}$$

It is seen that P acts to diminish, Q and R to increase the strain S. Cancelling the negative term containing P, we have

$$S\,(\text{max.}) = \frac{\frac{Q}{2}x + \frac{R}{4}x}{S}$$

Cancelling the positive terms, containing Q and R, we have

$$S\,(\text{min.}) = \frac{-P\left(\frac{x}{4} + \frac{l}{4}\right)}{S};$$

giving the least tension or the greatest compression. The pieces have been considered as having no weight, and P, Q and R, as temporary loads. To find T and U we have

$$T.C\,D - P.\frac{l}{4} + D.\frac{l}{2} = 0.$$

$$-U.u + D.\frac{l}{4} = 0.;$$

and putting for D its value, we get

$$T = \frac{-P\frac{l}{8} - Q\frac{l}{4} - R\frac{l}{8}}{C\,D}$$

$$U = \frac{P.\frac{3}{16}l\;Q.\frac{l}{8} + R.\frac{l}{16}}{u}$$

from which it appears that these posts receive the maximum strain under a full load.

To find V, the section $a\,\beta$ and the centre of moments 0^1, are employed; giving

$$-V\left(y + \frac{l}{2}\right) - Q\left(y + \frac{l}{2}\right) - R\left(y + \frac{l}{4}\right) + W.y = 0,$$

and substituting for W its value

$$\tfrac{3}{4}R + \frac{Q}{S} + \frac{P}{4};$$

$$V = \frac{-R.y\frac{+l}{4} + Q\frac{y+l}{2} + P.\frac{y}{4}}{y + \frac{l}{2}}$$

from which

$$V\,(\text{max.}) = +\frac{P.\frac{y}{4}}{y + \frac{l}{2}},$$

the greatest tension, and

$$V\,(\text{min.}) = \frac{-R \cdot \frac{y+l}{4} - Q\frac{y+l}{2}}{y + \frac{l}{2}},$$

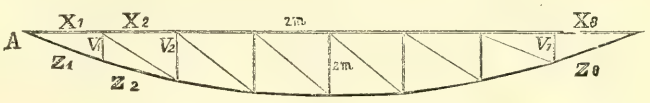
the maximum compression.

The rule may be expressed as follows :

Assume all points of support to be loaded, and obtain the equation of moments for the piece under consideration ; disposing the terms so that the influence of each load is represented by a single term of determined sign. Then strike out, first, all negative terms; then, all positive terms, and the required maximum or minimum is determined.

The calculations in the following example are made according to this rule. The construction is a parabolic girder of 16 metres span, as represented in the diagram (Fig. 2).

Fig. 2.



The weight of the bridge is 1,000 kil. to the metre ; the passing load is assumed to be 5,000 kil. to the running metre ; half being supported by each girder. As the length of each panel is 2 metres, each point of support bears a permanent load of 1,000 kil. and a passing load of 5,000 kil.

To determine the strain X_1 pass the section $\alpha\,\beta$ through the first bay and take C as centre (Fig. 3).

$$0 = X_1 \cdot \tfrac{7}{8} + D \cdot 2$$

with full load

$$D = 6000\,(\tfrac{1}{8} + \tfrac{2}{8} + \tfrac{3}{8} + \ldots + \tfrac{7}{8} = 21000$$

substituting, we have for the greatest strain

$$X_1\,(\text{min.}) = -48000.$$

Again taking moments about B

$$0 = -Z_1 \cdot 0{,}8 + D \cdot 2$$

and substituting for D its value

$$Z_1\,(\text{max.}) = +52500$$

To determine V_1, we make use of the section $\gamma\,\delta$ (Fig. 3), and the centre R. We have

$$0 = -V_1\,2{,}8 = D \cdot 0{,}8$$
$$V_1\,(\text{min.}) = -6000.$$

To find X_2, Y_2, Z_2, pass the section $\varepsilon\,\zeta$, as in (Fig. 4).

For X_2 with E as centre, we obtain

$$0 = X_2\,1{,}5 + D \cdot 4 - 1000.3 - 5000\,2,$$

or

$$0 = X_2 \cdot 1{,}5 + 1000\,(\tfrac{1}{8} + \ldots + \tfrac{7}{8})\,4 + 5000\,(\tfrac{1}{8} + \ldots + \tfrac{7}{8})\,4 - 1000 \cdot 2 - 5000 \cdot 2$$

In this equation the effect of the load 5000 kil. on the point B differs in two terms; one, $+5000 \cdot \frac{7}{8} \cdot 4$, is the addition to the reaction at the abutment; the other $-5000 \cdot 2$, is the direct effect upon the girder.

These terms should be brought together in the equation giving

$$0 = X_2\,1{,}5 + 1000\,[(\tfrac{1}{8} + \ldots + \tfrac{6}{8})4 + (\tfrac{7}{8} \cdot 4 - 2] + 5000\,[(\tfrac{1}{8} + \ldots + \tfrac{6}{8})4 + (\tfrac{7}{8} \cdot 4 - \ldots)]$$

It is here seen at a glance that the positive products are in excess, giving

$$X_2\,(\text{min.}) = -48000.$$

Taking R as the centre of moments, and arranging terms,

$$0 = Y_2\,1{,}68 - 1000[(\tfrac{1}{8} + \ldots + \tfrac{6}{8})(0{,}8 - 2{,}8 - \tfrac{7}{8} \cdot 0{,}8)] - 5000(\tfrac{1}{8} + \ldots + \tfrac{6}{8})0{,}8 + 5000(2{,}8 - \tfrac{7}{8} \cdot 0{,}8)$$

Among the seven terms containing the factor 5,000, which represent the effects of passing loads, six are negative and one positive. Cancelling the positive term

$$0 = Y_2 \cdot 1{,}68 - 1000[(\tfrac{1}{8} + \ldots + \tfrac{6}{8})0.8 - (2{,}8 - \tfrac{7}{8} \cdot 0{,}8] - 5000(\tfrac{1}{8} + \ldots + \tfrac{6}{8})0{,}8.$$
$$\therefore Y_2\,(\text{max.}) = +6250.$$

Removing the six negative terms and reducing

$$Y_2\,(\text{min}) = -6250$$

It follows also, that $Y_2 = 0$, if all the terms are retained; that is if all points of support are loaded.

To find Z_2, take B as the centre of moments.

$$0 = -Z_2 \cdot 0{,}835 + 1000(\tfrac{1}{8} + \ldots + \tfrac{7}{8})2 + 5000(\tfrac{1}{8} + \ldots + \tfrac{7}{8})\,2$$
$$\therefore Z_2\,(\text{max.}) = 503000.$$

To find V_2, make use of the section $\eta\,\vartheta$ (Fig. 5), and the centre S.

$$0 = -V_2 \cdot 8 - 1000\,[(\tfrac{1}{8} + \ldots + \tfrac{6}{8})\,4 - (8 - \tfrac{7}{8} \cdot 4] - 5000\,(\tfrac{1}{8} + \ldots + \tfrac{6}{8}) + 5000\,(6 - \tfrac{7}{8} \cdot 4)$$
$$\therefore V_2\,(\text{min.}) = -75\,0$$
$$V_2\,(\text{max}) = +560.$$

The strains for the several pieces as determined by the above rule are shown in (Fig. 5.)

Fig. 3.

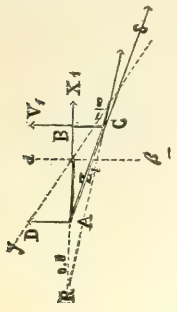


Fig. 4.

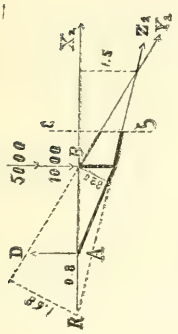


Fig. 5.

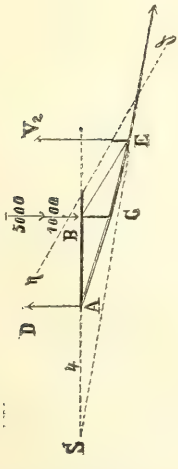
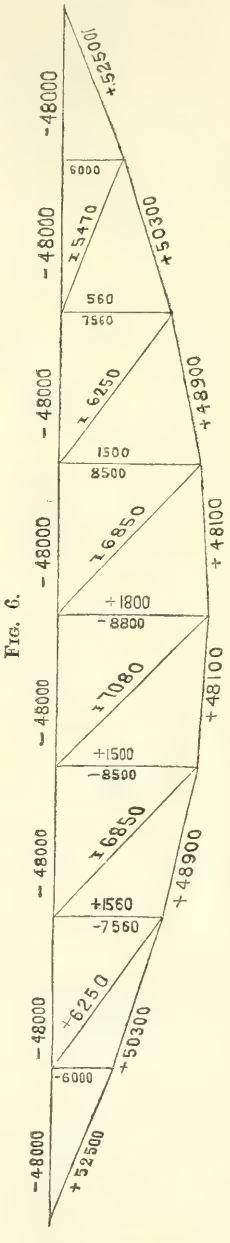


Fig. 6.



Toronto, Grey, and Bruce Railway.—The directors have been authorized to issue bonds to the amount of $160,000. It is officially stated that $263,000 have been expended on the surveys and works.

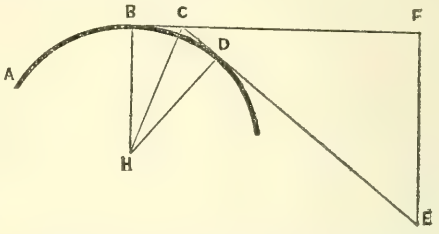
A NOTE ON RAILWAY CURVES.

By Wm. Rock, C. E.

Having run a curve of given radius from A to B, and a tangent from B to F; let it be required to continue the curve to some point D, so that the tangent D E shall pass through E at a given distance from E.

Let R = the given radius B H or H D; let B F = d and E F the given distance = p.

Let x = tangent of B H C, one half of the central angle, corresponding to the proposed extension of the curve.



Now by the principles of trigonometry, the natural tangent of F C E (=2 B H C) will be equal to $\frac{2x}{1-x^2}$. Also B C = R x, and C F = d − R x.

Therefore, E F = $\frac{2x}{1-x^2}(d-\mathrm{R}\,x)$. But this is the given distance p.

We have, therefore, $\frac{2dx-2\mathrm{R}x^2}{1-x^2}=p$.

From which we get $(2\mathrm{R}-p)x^2-2dx=-p$, which being solved gives

$$x=\frac{d\pm-(d^2+p^2-2\mathrm{R}p)^{\frac{1}{2}}}{2(\mathrm{R}-p)}$$

which is the formula required.

The double sign indicates that two different tangent lines from the same curve may pass through the given point. In practice there is no difficulty in determining which sign to use.

This formula is very useful in changing the position of a long tangent.

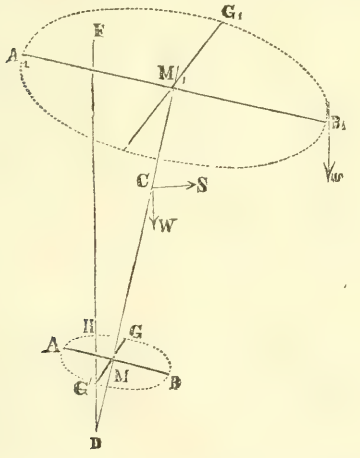
Army Telegraphy.—Army telegraphy by means of signal flags and lights is to be introduced into India, and complete sets of apparatus are being sent from England for the purpose. Classes of instruction are also to be formed.

Ten new gunboats are to be added to the British navy.

THE MECHANICS OF TABLE TIPPING.

Translated from "Zeitschrift für Mathematik und Physick."

In shoving a table the friction between its feet and the floor must be overcome. To turn a table in a circle about its axis (all the feet touching the floor), if the force is applied near the circumference of its top, the same amount of friction is to be overcome; but the force required is less in the same ratio as the lever arm of the applied force is greater than the lever arm of the point of contact of the foot; both being measured from the vertical axis of the table. In turning a three-legged table about one of its feet, only two-thirds of the sliding friction has to be overcome, and this is accomplished by means of a longer lever-arm; so that not more than one half the force required for shoving is needed for turning. In tipping a table not only is the force thus reduced, but friction is generally of no account. The whirling table is nearly in the condition of the body represented in the figure as rolling or whirling along the



circle A G B G′ which passes through the feet. The rotation about the vertical axis M M′ requires only the overcoming of rolling friction, which, as is well known, is but a small fraction of sliding friction. The greatest resistance that can result is insignificant.

Suppose the table revolves in the direction AGBG′ about its axis M M′, then the circle through the feet rolls in an opposite direction along the circle B H K. This motion is maintained by the weight C W = W, and the centrifugal force C S = S, acting at the centre of gravity C of the table; and besides these a vertical force w acts at the point B_1.

Let a = the angular velocity about D F′.
η = the rotation velocity about M M′.
ψ = the angle of inclination M D F′.
r = the radius of the foot-circle.
R = the distance of the centre of gravity C from the vertical axis D F′.
T = the moment of inertia.
$M C = h$; $M M_1 = H$; $M_1 B_1 = \rho$.

The foot-circle in a unit of time passes over the space $(\eta + a \cos \psi)\, r$ along the circumference B H K. As the radius of this circle is

$$R - h \sin \psi + r \cos \psi$$

the space is

$$a\,(R - h \sin \psi + r \cos \psi.$$

Hence

$$a\,(R - h \sin \psi) = \eta\, r.$$

The couple W acting at C and the vertical resistance at B, give the moment.

$$W\,(r \cos \psi - h \sin \psi.$$

The couple of the centrifugal force at C and the horizontal resistance at B, give the moment.

$$\frac{W}{g} a^2\, R\,(r \sin \psi + h \cos \psi)$$

The couple of the pressure w at B, and of the vertical resistance at B give the moment.

$$w\,(\rho \cos \psi - H \sin \psi - r \cos \psi.$$

The last two couples act against the first hence

$$W\,(r \cos \psi - h \sin \psi) - \frac{W}{g} a^2\, R\,(r \sin \psi + h \cos \psi)$$
$$- w\,(\rho \cos \psi - H \sin \psi - r \cos \psi) = \tfrac{1}{2}\, a\, \eta\, T \sin \psi.$$

Finding the value of a we have

$$a = -\frac{\eta\,(\frac{1}{2}\, T \sin \psi + \frac{W}{g} r\,(r \sin \psi + h \cos \psi}{2\,\frac{W}{g}\, h\,(r \sin \psi + h \cos \psi) \sin \psi}$$
$$+ \sqrt{\left\{ \frac{\eta^2 \left[\frac{1}{2} T \sin \psi + \frac{W}{g} r\,(r \sin \psi + h \cos \right.}{\left[2\,\frac{W}{g}\, h\,(r \sin \psi + h \cos \psi) \sin \psi\right]} \right.}^{2}$$
$$+ \frac{W(r \cos \psi - h \sin \psi) - w(\rho \cos \psi - H \sin \psi - r \cos \psi.)}{\frac{W}{g} h\,(r \sin \psi + h \cos \psi) \sin \psi}$$

The radical in this case should be taken as positive.

If η is very small we have approximately

$$a = \sqrt{\frac{W\,(r - h\tan\psi) - w\,(\rho - r - H\tan\psi)}{\frac{W}{g}h\,(r\tan\psi + h)\sin\psi}}$$

The velocity a R of the centre of gravity C, and that of the middle point M_1 of the table approximately, is equal to

$$\eta\, r + a\, h \sin\psi$$

or if η is small enough to $a\,h\sin\psi$. Hence the velocity is nearly

$$a\,R = \sqrt{\frac{[W(r - h\tan\psi) - w\,(\rho - r - H\tan\psi]h\sin\psi}{\frac{W}{g}(r\tan\psi + h}}$$

The apparent rotation β of the top, due to the rotation about a line parallel to A_1 B_1, or the angular velocity of the lowest point B_1 along the circumference of the top, is $a\cos\psi$; or a nearly, because ψ is small.

These formulas lead to the following conclusions. The table when tipped at the angle ψ requires no rotation about the axis M M_1 in order to maintain a uniform motion of rotation around the foot-circle. And no pressure w is needed to keep up this motion; since the weight and the centrifugal force are sufficient. For the values expressed in the formulas do not vanish if $w = 0$. All the work needed to maintain the motion is the little that would compensate for the loss of work due to rolling friction and slight concussions. To put the table in motion, it is only necessary to tip it a little, by a pressure at B_1 and a slight pressure elsewhere would initiate rotation about the foot. The table would be set in motion about a vertical D F′ with an angular velocity a; and this velocity has a considerable value even if the velocity η of the table about its own axis is zero. The smaller the angle ψ the greater this value; that is, the less the table-axis is tipped from the vertical and the smaller the force w, the greater is this velocity.

The actual motion of a point B_1 is composed of the rotation η about the axis M M_1 and of the angular velocity a about the axis D F′. In general η is small and a large; making the radius R from D F′ to C small. Hence the table-tippers need step around the table with the slightest speed in order that their hands may feel a very quick motion corresponding to the angular velocity a, or the apparent motion β, with which the point B_1 rises and falls. The periodic descent of the point B_1 naturally causes a pressure w from the hand applied; and this point revolves automatically, *i. e.*, without the will or consciousness of the company. Again, the hands of the company help the motion in the direction of the rotation by means of adhesion; thus compensating for the slight loss of living force resulting from rolling friction and slight impact. If the rotation η is zero, lateral pushing is not necessary; the whirling can be kept up by standing still and exerting the slight periodic pressure w.

It is not to be denied that the motion of the table is something extraordinary. Very slight vertical and lateral pressures are sufficient to keep a very heavy table in motion. Even when the rotation η is quite small, there may result a quick motion of progression (a R), and at the same time a violent rolling motion (a), causing a rapid succession of wave-like risings and fallings running round the table. While the motion of rotation is in the direction G_1 B_1 the progressive motion is in the opposite direction B_1 G_1, and there is a simultaneous elevation and depression of points. While one follows the motion of the table, it now bounds against his hand, now recedes from it. These motions are of course perceived, and they seem very extraordinary as well as energetic. All depends, however, not upon the will of any single person, nor yet upon that of the whole company, but the phenomena are the result of the mechanical laws.

Indian Telegraphy.—On the completion of the submersion of a cable from Batavia to Singapore, Capt. Halpin was to commence laying down what are known as the "British Indian Extension cables," from Singapore to Penang and Madras.

A Whitworth Steam Hammer for Turkey.—The Turkish Government has ordered for its Zeitoun-Bournou Works an 8-ton Whitworth steam hammer. It is understood that the hammer is now on its way to Turkey. The hammer will of course be able to execute very heavy forgings.

TABLE OF RAIN-FALL, ETC., FOR FIVE YEARS.

By Prof. ORAN W. MORRIS, New York City.

Table of Rain-fall for each month; with the Annual Amount, the Number of Days on which Rain and Snow fell, the Mean Quantity for each Stormy Day, etc., for Five Years.

Year.	Jan.	Feb.	March	April.	May.	Jnne.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Yearly Mean.	Amount.
	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.
1866.....	2 56	10.09	2.28	4.09	4.46	4.38	1 67	4.81	4.85	5.28	3 84	3.92	4.35	52.23
1867.....	2 54	5.53	4.09	2.47	5.70	10.18	5.76	7 675	0 78	5.12	2.25	2.56	4 554	54.655
1868.....	4.00	2.31	3 69	6.42	7.19	4.66	6.44	8.31	9.60	2.01	5.13	4 27	5 34	64 03
1869.....	4 18	7 29	5.84	1.57	5.75	4.72	4 445	1 85	4.07	6.78	3.25	5.79	4 63	55 535
1870.....	5.10	4.47	4.17	5.61	3.08	2 85	4.72	3.79	2.38	5.72	2.41	2 83	3.93	47 13
Mean.....	3.68	5.94	4.01	4.03	5.23	5.36	4.61	5.30	4.34	4.98	3 37	3.87	4.56	54.716

Number of Days in which Snow or Rain fell.

	Year.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Total.	Inches.
Rain.....	1866	5	6	11	12	10	14	10	16	12	6	9	6	117	
Snow.....	....	9	6	5	..	..	..	..	..	..	..	3	4	27	.34
Rain.....	1867	1	9	6	11	18	13	13	19	6	12	9	6	123	
Snow.....	....	9	6	13	5	1	..	..	..	.	..	2	8	45	.33
Rain.....	1868	4	2	5	13	19	14	11	15	21	13	10	3	130	
Snow.....	....	8	5	3	4	..	..	..	..	..	..	1	5	26	.41
Rain.....	1869	8	8	6	8	20	18	13	8	8	14	8	8	127	
Snow.....	....	6	9	9	5	..	..	..	..	..	..	6	8	44	.32
Rain,.....	1870	13	7	5	13	18	23	13	15	6	13	8	5	139	
Snow.....	....	5	7	11	3	..	.	..	..	..	..	1	7	34	.27

The table is intended to show the quantity of water that fell, each month, on Manhattan Island, and thus indicate the necessity for sewers of sufficient capacity to carry off the surplus water, without danger of an overflow and consequent damage to buildings not only, but to merchandise.

The mean quantity for the five years is greater than it is generally thought to be; that of some months is enormous for this country, as for instance, in February, 1866, which was 10.09 in., and in June, 1867, 10.18 in.; at both times much damage was done, for the sewers were choked by the quantity of water pouring into them.

The largest number of days in which rain or snow fell was 173, in 1870, in which year there was the least in quantity. The least number was 151 in 1866, when there were 2.486 in. less than the *mean* quantity. In 1868, the number was 156; but the quantity was the largest, 9.314 in. more than the *mean*.

In *some* of the storms that occur, there are large quantities of water deposited, as for instance, July 24th and 25th, 1868, in a rain of 15 hours there fell 3.05 in. Again, in August, in a succession of showers from the 5th to the 8th, there fell 4.57 in.; and in September from 3 P. M. of the 3d to 3.15. P. M of the 4th, 24¼ hours, 4.28 in. fell, and at 5.50 P. M. of the same day to 3.20 A. M. of the 5th, 1.19 in. more fell, thus making 5.47 in. 29½ hours. This quantity could not pass off by the sewers then built, and the consequence was much damage and disease produced from the ponds formed. In some sudden showers, more in proportion frequently falls in a short time, as on the 4th of August, 1868, in $3\frac{35}{60}$ hours there was a fall of 1 in.

Locomotives in Belgium.—The Belgian Minister of Public Works recently promised to give out orders for 30 locomotives, to assist Belgian mechanical firms during the present crisis. It does not appear, however, that the orders have yet been actually given.

IRON AND STEEL NOTES.

THE IRON MANUFACTURES OF ST. LOUIS.—The St. Louis "Times" has an extended review of the business of that city for the last year, from which we take the following account of its iron industry:

For those who take an especial interest in the growth of our city there is probably no feature more gratifying than the development of its manufacturing interest; all departments of trade have a common interest in it; an increase of manufactories gives a much more stable feeling to all, and especially to the landholder, for he sees increased population, more dwellings and more shops. The Secretary of the Treasury, in his late report, takes special care to congratulate the people upon the general manufacturing interests of the country. According to the census report, our manufacturers represent $43,667,000 of capital, with a consumption of $55,500,000 of raw material, the value of whose productions are over $100,000,000, an increase in ten years of $73,000,000. Now that St Louis has got to be a producing as well as a convenient trading point, its destiny is fixed. Expect all we want and it shall be realized in proportion to the growth of its manufactories.

To us the most important is the manufacture of iron. So long as our merchants could buy stoves in Cincinnati, and even further east, and lay them down in St. Louis cheaper than they can be produced, any other trading point would offer as good advantages for dealing in this commodity, and our stove manufacturers, so long as they had to purchase iron from Scotland, Tennessee, and Ohio, from which to manufacture their stoves, could probably get along about as well at any other point as St. Louis, but now that they get a superior article to what they formerly used delivered to them at $4 to $5 per ton less than it can be purchased in other markets, at a saving of $5 per ton freight, which they formerly paid, they are enabled to make a superior stove at less cost than can be had anywhere else. These advantages are causing this branch of business to gain very rapidly, one company having manufactured 40,000 stoves during the present year and several others have done nearly as well. The capital thus invested is $2,650,000, with a yearly production of $2,500,000. New manufactories have been built and old ones enlarged. We have no longer to get our nails from the Ohio, and rely upon its uncertain navigation, but we now have them, made at home, of a superior quality, and from our own iron. During the present year a large rolling mill (in addition to the one already in operation) has been started, and we will soon be independent of other markets for all descriptions of merchant iron. A spike mill is also being constructed, and will be in operation early in the spring. The proprietors of this are strangers amongst us, but they see that destiny has marked St. Louis, and are anxious to cast their lots amongst us.

No longer shall we have to import from England and Pennsylvania iron for our railroads. Early in the spring the Vulcan Iron Works, with an invested capital of $1,000,000, will be turning out rails at the rate of 40,000 tons per annum, and probably before another year will be manufacturing steel rails of a better quality and less cost than ever produced in this country, as our metal is better adapted for this purpose than any made. A gentleman who has given this subject thorough investigation, feels so well satisfied regarding it that he is working up a company of $1,000,000 capital, one-half to be taken in Europe, for the purpose of manufacturing steel rails here. St. Louis, the grand railroad centre of the country, with its great trunk lines stretching from the Atlantic to the Pacific, from the Gulf to 3,000 miles north, with a better and a cheaper iron, certainly offers something enticing for the prosecution of this business.

Very essential to the successful working of iron is a good fire clay. The supply and quality of what we have have both been thoroughly tested; the supply is inexhaustible, and the quality has proven to be very superior. There are several extensive manufacturers of it, and they export largely to Eastern cities. This is quite a change, as it has not been many years since fire-brick were imported from Europe.

The coke works at East St. Louis will be in operation in March next, giving us, it is hoped, a superior coke at a much less cost than that we are now compelled to boat down the Ohio and up the Mississippi — a long, uncertain, and hazardous route, making the original cost more than double, and supply precarious. If the works effect what is proposed, it will be a great achievement for our manufacturing interest. They are under the management of an able engineer, who has constructed similar works in Germany, and he entertains no doubt of this being a success. We shall not enumerate all the interests in connection with the iron business, but we are now started, and one department of manufacture begets another, just as an increase in the family gives employment to a nurse.

One of our iron firms have recently contracted to equip a line of railway 125 miles long, the contract amounting to over $400,000. The iron for this contract comes from our own mines, the wood from our hills, hundreds of laborers are employed, to whom our farmers furnish the food they eat and the cotton and wool to clothe them. These things are attracting great attention from a distance, and people are constantly visiting us with a view of investing or settling in this fortunate land, and they do not go away disappointed with what they see. All are struck with the substantial and costly nature of our manufacturing establishments. They speak the convictions of the builders.

Up to January, 1869, we had in the State seven charcoal furnaces, producing about 40,000 tons of metal per annum, and one rolling mill with a capital of $500,000, and capacity of 10,000 tons. We have now completed eight charcoal and seven stone coal furnaces, with an aggregate capital of $4,000,000, and capacity of 135,000 tons, three-fourths of which are situated at St. Louis. Of rolling mills, spike mills, bloomeries, etc., we now have four completed, and two under way; capital, $2,200,000, and capacity, 65,000 tons. This leaves the production of pig metal largely in excess of the home demand, and this surplus is compelled to find a sale in some distant market at a heavy expense. So long as this is the case, the opportunity is a good one for the erection of mills, foundries and shops of every description, and the superior quality and lower price of our metal will be a sufficient inducement. The last two years show a wonderful increase; but we think it only a presage of what is to follow. With all the essentials and of the best quality, and so contiguous, the iron manufacturing business, viewed in the future, assumes such proportions as to challenge the imagination to compass it.

The subsidiary iron works in and near the city are increasing almost monthly. Including the bolt and nut works with a capital of $150,000, the various foundries, stove works and other establishments, the capital so invested is not less than $5,000,000, with a yearly production of $9,000,000

Extensive Steel Works.—The Easton "Free Press" says the new steel rolling mill at South Bethlehem, Lehigh county, is 656 ft. in length, as at present. When completed it will be 1,600 ft. long. The wings are about 400 ft. in length. One of the stacks has been put in position, being 124 ft. in length. The engines to be used at this mill are all to be underground. South Bethlehem is destined to become an important manufacturing town. Its facilities for procuring coal, iron, lumber, and other materials needed for heavy work, are considerable, and the district in which it is situated is healthy and fertile.

Refined Iron.—Refined iron is hammered under the tilt hammer into narrow slabs, calculated to produce a sheet of finished iron two archines by one (56 in. by 28 in.), weighing when finished from 6 lbs. to 12 lbs. These slabs are called *balvanky* in Russia. They are put in the re-heating furnaces, heated to a red heat, and rolled down in three operations to something like a sheet, the rolls being screwed tighter as the surface gets thinner. This must be subsequently hammered to reduce its thickness and to receive the *glance*. A number of these sheets, having been again heated to a red heat, have charcoal, pounded to as impalpable a powder as possible, shaken between them through the bottom of a linen bag. The pile, then receiving a covering and a bottom in the shape of a sheet of thicker iron, is placed under a heavy hammer; the bundle, grasped with tongs by two men, is poked backwards and forwards by the gang, so that every part may be well hammered. So soon as the redness goes off they are finished so far as this part of the operation goes. So far they have received some of the *glance* or necessary polish; they are again heated, and treated differently in this respect, and instead of having the powdered charcoal strewn between them, each two red-hot sheets have a cold finished sheet put between them; they are again hammered, and after this process are finished as far as thickness and glance goes.—From "Russian Metallurgical Works," by Herbert Barry.

Iron Tonnage for River Navigation.—The popularity of iron steamers for interior navigation is steadily increasing, and one by one the cities of the West and South are learning the advantages of metal over wood for river tonnage, and are urging through their local newspaper press the importance of a gradual substitution of iron tonnage for that now in use. It is a well established fact that, by the substitution of metal for wood, a saving of 2,000 tons of weight to every 1,000 tons measurement is effected, with 10 in. less of draught and 10,000 cubic ft. additional capacity for freights. The additional expense is very slight, and even this will disappear when an increased demand for iron shipping shall necessitate the estabtishment of better and more perfect facilities for iron shipbuilding in the West. The city of St. Louis, being the Western iron centre, naturally favors the universal substitution of metal for wood as a material for river tonnage, and many smaller cities, including Pittsburg, Wheeling, Cincinnati, and Evansville, where facilities are at hand for the establishment of extensive yards for the building of iron ships, manifest a deep interest in the question. In building iron vessels for the lake trade, both Chicago and Milwaukee are also much interested. This is a movement which deserves hearty and honest encouragement from all parts of the country. A wooden boat costs an average of $45 per ton, and lasts an average of 5 years; while an iron boat, which costs an average of $50 per ton, will last, with fair usage, an average of 30 years, besides being lighter, drawing less water, and being less liable to destruction by fire. Another advantage is that iron boats could be used in winter with less danger from ice than wooden boats. These are important considerations, and with the general substitution of iron for wood in river tonnage, which must be brought about in a few years, we may look for a revival of river navigation throughout the West and Southwest that will enable the shippers of river freights to compete successfully with the railroad companies which now practically monopolize the business of inland transportation.—*Iron Age.*

RAILWAY NOTES.

The World's Railways—The extent and cost approximately of the railways of different countries at the close of 1868 was as follows:

	Length in miles.	Cost per mile in dollars.	Total cost in dollars.
United States	42,255	44,255	1,869,529,313
Great Britain	14,247	176,269	2,512,314,435
France.....	9,934	158,714	1,576,664,892
Prussia.....	5,926	126,171	747,689,345
Austria.....	4,429	73.915	327,369,534
Russia.....	4,317	160,922	724,700,274
Italy.....	4,109	93,108	382,580,776
Spain.....	3,429	107,156	376,437,922

Besides the above, India had 4,092 miles, costing $95,769 per mile; Canada, 2,353 miles, costing $70,000 per mile; and South America, 1,424 miles, costing $116,000 per mile. The whole length of all the railways in the world is about 120,000 miles, costing in round numbers $10,000,000,000. This vast system of conveyance is reckoned by the Statistical Office at Berlin, Prussia, to transport annually 900,000,000 passengers, and 450,000,000 tons of freight; to use 40,000 locomotive engines, and to give regular employment to over 1,000,000 persons.—*Am. Railway Times.*

A narrow Gauge (2 ft. 6 in.) will be built in Penn., says a correspondent of the "Iron Age," from Allentown to Harrisburg, via Reading and Lebanon, along the Tulpehocken and Swatara creeks. The Fairlie Engine will be used, the cost of construction and equipment being ⅓ that of the 4 ft. gauge. A speed of 25 miles an hour is expected, and freight carried at 1 cent a ton per mile.

Mr. Chas. H. Prior has been appointed Superintendent of the Iowa and Minnesota, and Iowa and Dakota divisions of the Milwaukee and St. Paul railway; also, of the Hastings and Dakota railway, in place of D. C. Shepard, Esq., resigned.

STATEMENT of the export of rails from Great Britain, compiled from official returns published by authority of the House of Commons.

COUNTRIES.	Month ending Nov. 30.		
	1868. Tons.*	1869. Tons.	1870. Tons.
AMERICA.			
United States	22,573	16,728	33,106
British	875	63	885
Cuba	20	549	....
Brazil	1,301	777	1,748
Chili	173	126	1,826
Peru	1,390	2,686	....
EUROPE.			
Russia	819	4,285	2,766
Sweden	....	1,424	93
Prussia	1,352	6,349	3,141
Illyria, Croatia, and Dalmatia	....	1,234	963
France	33	90	....
Holland	2,937	1,121	205
Spain and Canaries	2,214	969	1,235
ASIA.			
British India	1,108	12,113	6,236
Australia	2,506	2,129	287
AFRICA.			
Egypt	4	3	68
OTHER COUNTRIES.	1,449	6,781	6,751
Total	38,754	57,427	59,310
Pig Iron to U. S.	8,508	9,475	6,819

COUNTRIES.	Eleven Months ending Nov. 30.		
	1868. Tons.	1869. Tons.	1870. Tons.
AMERICA.			
United States	278,035	311,097	415,730
British	18,275	26,869	39,754
Cuba	3,001	1,541	3,583
Brazil	3,733	4,039	5,368
Chili	1,797	3,220	17,338
Peru	4,928	23,653	15,321
EUROPE.			
Russia	113,440	281,236	231,252
Sweden	1,787	5,835	3,000
Prussia	7,760	23,048	50,083
Illyria, Croatia, and Dalmatia	11,757	26,229	40,717
France	214	4,834	405
Holland	26,584	12,408	17,242
Spain and Canaries	10,496	13,972	13,420
ASIA.			
British India	69,801	97,457	163,982
Australia	11,613	24,352	9,020
AFRICA			
Egypt	11,777	6,779	2,371
OTHER COUNTRIES.	34,924	79,719	74,485
Total	609,922	946,288	1,103,071
Pig Iron to U. S.	93,073	141,967	116,116

—*Bulletin of the American Iron and Steel Association.*

* Tons in all cases 2,000 lbs.

CONTINUOUS FREIGHT TRAFFIC OVER LINES OF DIFFERENT GAUGES.—A correspondent, Mr. Joseph P. Noyes, of Binghampton, writes us on the above subject as follows: All, or nearly all freight cars have a stout timber or plank crossing under the body of the car, over the centre of each truck, and projecting an inch or two beyond each side of the car, thus forming four points upon which a loaded car may rest without injury, independent of the trucks.

Upon these same planks are placed three castings, namely the pivot and two side bearings.

What I propose is, to have a lifting apparatus, with most of its working parts in a pit under the track, to lift a loaded car bodily off the trucks by the four points above mentioned, run out the trucks of one gauge, and run in trucks of another gauge, and let the car down upon them. The pivots, side bearings, and brake chains would have to be of uniform pattern; but in other respects all the existing variety of cars and trucks could be used, and every road would keep its *running gear upon its own road.*

A 10-horse engine would furnish power to transfer several hundred cars in a day, with switch engines to move them.

LOCOMOTIVE BUILDING—EXTENSIVE ESTABLISHMENT.—The locomotive works of M. Baird & Co., North Broad street, are the largest in this country, or perhaps in the world. 1,900 men are now employed in the various shops, which occupy the space from Willow street to near Spring Garden, and from Broad to Fifteenth streets. Rather more than one locomotive is completed and sent out for every working day in the year, to supply the wants of railroads in every part of the United States and portions of Europe. Three locomotives, one nearly completed, are intended for the Don Pedro Railroad, in Brazil. Each of them weighs 90,000 lbs., being the heaviest locomotives yet constructed. They are to be used as freight engines, and on a road with heavy mountain grades. This firm are also constructing small mining locomotives that weigh but 14,000 lbs., and are to be used in place of mule-power, in hauling coal from the head of mines. They are 5 ft. high and 5 ft. broad.—*Philadelphia Ledger.*

RAILWAYS INTO NEW YORK.—The census returns from the New Jersey suburbs present an emphatic proof of the increasing business of New York, whose surplus population is overflowing rapidly in that direction, but nothing more clearly shows the immense increase in the general business of the country than the history of the railroad traffic in New Jersey for the decade just past.

It is scarcely 10 years since all the roads leading through New Jersey to New York harbor from the West converged at Bergen Hill, and from that point to Jersey City were dependent on the New Jersey Transportation Company. That single road was adequate to the entire railroad business from the West through New Jersey to New York.

The Erie, the Northern, the Morris and Essex and the Central were all tributaries to the New Jersey road, and their combined traffic 11 years ago did not exceed that of the single New Jersey road at the present time. During the decade the Erie has established a terminus and ferry of its own; the Morris and Essex has reclaimed and utilized a vast tract of water front, and adopted the Hoboken Ferry; the Central has filled in a

former waste and established the most commodious ferry in this or any other country; and now within 10 years we see what was a single avenue of traffic enlarged to four, each equal in the volume of its business to all the roads when formerly combined in one.

If we compare the respective time tables, we learn that the number of trains on each road is about the same as on the combined roads in 1860; so that we have demonstrated the astounding fact that the railway business across and through New Jersey has increased 400 per cent. in 10 years. Much of this increase is due to the migration of New York families, who find all that is requisite within an hour's ride.

The rush from the city was never so great as during the present season, and it suggests the inquiry whether the facilities for transportation are increasing in a corresponding degree.

The Midland Road is fast approaching completion. It extends through New Jersey between the Erie and the Morris and Essex roads.—*N. Y. Evening Post.*

ORDNANCE AND NAVAL NOTES.

We understand there is some idea of forming mitrailleuse camel batteries in India. The gun is to be mounted on and fired from the camel's back, the latter kneeling down at the word "action." At present this idea is not even in an experimental stage; but in all probability such trials will be made. This reminds us of an amusing story connected with the Ordnance Select Committee. It was at one time proposed to fire mountain guns off the backs of mules that carried them. It was urged that this would obviate the necessity of dismounting the gun from the mule's back and mounting it on its carriage; a mountain battery could thus come into action in far less time. This proposal was warmly taken up by the committee, who forthwith proceeded to test its feasibility. A mule or donkey was procured, and a small gun strapped firmly to a cradle resting on the pack-saddle, so that the muzzle of the weapon pointed over the donkey's tail. The animal, so the story goes, was then led into the marshes at Woolwich, accompanied by the committee and several "big wigs," who were attracted by such a novel experiment. On arrival at the butt the gun was loaded, the donkey turned with his tail towards the earthen mound, and the usual preparations were made for firing by means of a lanyard and friction tube. Hereupon, however, one of the committee remarked that this mode of firing might possibly derange the aim by the jerk on pulling the lanyard. A discussion followed, and it was finally arranged to fire the gun by a piece of slow-match tied to the vent. This was accordingly done, and the match duly ignited. Hitherto the donkey had taken rather a sleepy interest in the proceedings, but somehow the fizzing of the match on his back caused him first to prick up his ears, then to lay them back, and finally to begin to turn round. The committee were thunderstruck, and "skedaddled" in all directions; the secretary threw himself flat on his face; there was a moment of agonizing suspense, then —bang—the shot went ricochetting away in one direction, while the wretched donkey turned a complete somersault in the other.—*Globe.*

The report of the special committee appointed to carry out comparative experiments with the mitrailleuse and Gatling guns has been published at Woolwich. The committee, which consists of Colonel E Wray, C.B., R.A. (president), Captain the Hon. F. Foley, R.N., Colonel G. Shaw, R.A., Lieutenant-Colonel Fletcher, Scots Fusilier Guards, Captain Beaumont, R.E., Captain Noble R.A., and Lieutenant-Colonel Heyman, R.A. (secretary), offer no opinion as to the merits of the rival weapons tried in competition, but give the results of each experiment in full detail in a series of tables, with a simple column of remarks relative to the conditions of the various trials, and the general conclusion is decidedly in favor of the small Gatling of ten 0.42 in. barrels. In a special competition between this gun and the Montigny mitrailleuse of 37 barrels, the former made 618 hits in 3 min. 31 sec. in 720 rounds at 600 yards; the Montigny, at the same range and with the same number of rounds, scoring 538 in 4 min. With 555 rounds at 800 yards the result was even more favorable to the Gatling, which made 439 hits in 2 min. 26 sec. against the Montigny's 292 in 3 min. 8 sec. The trials against field guns firing shell and infantry armed with Snider and Martini-Henry rifles were likewise favorable to the small Gatling, and a comparison of the total effects of the experiments versus weight of ammunition expended gives the following figures:—The small Gatling, weighing 3 cwt., expended 492 lbs. of ammunition, and scored 2,803 hits; the Montigny mitrailleuse of 3 cwt. expended 472 lbs. and scored 1,708 hits; the 12-pounder breech-loading field gun, weighing 8 cwt., expended 1,232 lbs. and scored 2,286 hits: and the 9-pounder muzzle-loader, weighing also 8 cwt., expended 1,013 lbs., and made 2,207 hits.

German Light Field Guns.—It is stated that the German infantry have recently been armed with a new weapon, designed for mountainous and guerilla warfare, which supersedes the light field artillery. It is a small portable field-piece, weighing about 35 lbs., and was tested in the war of 1866. It can be carried by two men, and ten shots a minute can be fired with it. Its range is at least 6,000 paces. Thousands have been distributed to the army.

ENGINEERING STRUCTURES.

Central Pacific Wharf in San Francisco Bay.—The San Francisco "Alta California" says: "A wharf, 11,000 ft. long, running out to a depth of 24 ft. at low tide, and of 31 ft. at high tide, in a bay like that of San Francisco, having 12 railroad tracks upon its last 1,000 ft., a wide carriage way, a spacious passenger depot, and railroad offices, warehouses, and outside storage for 40,000 tons of grain or other merchandise, three large docks, one of which affords ample space for five of the largest steamers or clippers afloat, is not often seen, even in this age of railroad and engineering wonders. Such a structure has been completed by the Central Pacific Railroad Company on the Oakland or east side of the Bay of San Francisco. The extreme end of the main wharf is only 3 miles from the foot of Second street, where freight is landed in this city, and is less than 2½ miles from the foot of Pacific street, where passengers are set down

on this side. It would be much more difficult to build such a long wharf with safety on our side of the bay, because the bottom here is a yielding mud, but on the Oakland side there is a hard clay bottom. Nothing has been neglected in the quality of material used and workmanship employed, to make the wharves the very best ever built in the United States. Experts in the construction of such work, army and other engineers, who are familiar with like structures in Europe and America, all agree in saying that, for engineering skill, mechanical execution, and solidity and excellence of all the material employed, the work is not surpassed by any they ever examined. The piles used, where the water deepens, are 65 ft. long, and are 42 to 54 inches in circumference, or as heavy as the mainmast to the largest clipper. They are all of the very best pine, which, for lasting qualities under the water, is one of the best kinds of wood. The main wharf—for 1,000 ft. east of the latter there are two wharfs, one for Oakland local trains, and one for the regular freight and passenger cars of the through overland road—is 800 ft. wide at the extreme or western end, and on it are pens for 500 cattle, 2 immense warehouses (one 50x500, another 50 x 600), with the passenger depot, 75x305 in size. The piles were driven into the bottom to a depth of 18 ft. They are set 10 ft. apart, parallel with the course of the wharf, and 6 and 7 ft. apart across it. In the docks, or slips, there is a double row of of spring or fend-off piles, and the regularity and neatness with which they are laid is especially worthy of attention."

The Omaha Bridge.—The work for the Omaha Bridge is progressing rapidly, and it is the expectation of the parties in charge that the bridge will be ready for the passing of trains within a year. The foundations consist of 11 piers, formed of cast-iron tubes 8½ ft. in diameter, which are sunk to the bed rock underlying the river at a depth varying from 40 to 73 ft. below the surface of the water. Work is in progress on 7 of the piers, and will be commenced on the remaining 4 piers in a few weeks. The pneumatic process is used in sinking the columns for the deeper piers, but when the bed rock is within 50 ft. of the surface of the water, it has been found practicable to sink the columns without resorting to that process. The spans are 250 ft. each, to be elevated 50 ft. above high water, making the entire height of the longest pier 145 ft. above the bed rock.

NEW BOOKS.

A Complete Treatise on Cast and Wrought Iron Bridge Construction, Including Iron Foundations. In three parts : theoretical, practical, and descriptive. Illustrated by numerous examples, drawn to a large scale. Third edition, carefully revised and considerably enlarged, by William Humber, Assoc. Inst. C. E., Mem. Inst. M. E. London: Lockwood & Co. For sale by Van Nostrand.

Humber's great work is too well known to require a detailed account of its merits here. This new edition, however, possesses some advantages over the older ones, which may be enumerated.

Much has been added to the theoretical part, especially to Chapters III. and VII. In the latter an attempt has been made to lead the reader on to a clear conception of the action of shearing forces and bending moments on the several parts of open-webbed girders, with both parallel and inclined booms. This has necessitated the introduction of elementary matter, which the more advanced student will be able to pass over.

The Chapters on Arches and Suspension Bridges have been entirely rewritten ; they will be found suggestive rather than exhaustive.

The results of some recent experiments have been added to the Tables of the strength of cast and wrought iron and steel ; and the Tables of dimensions, weight, and cost of various iron bridges have been extended.

The Chapter on the "Practical Application of the formulæ" will be found to contain much additional information. The recapitulation of formulæ, which appeared at the end of this chapter in the first edition, has been in the present instance omitted, as the copious Index and enlarged Table of Contents will enable the formulæ given for any case to be readily found.

To the "Descriptive" portion of the treatise, four examples of bridges have been added—all of the suspension class ; they were really a necessary complement to the work, as in the first edition no illustrations were given of structures of this type.

The whole of the letter-press has been subjected to a strict revision ; and great care has been taken to correct the typographical and other errors which were discovered in the few stereotype plates that have been retained.

Those not already familiar with the work will find this the most complete treatise upon Iron Bridge construction in the English language.

The Theoretical part discusses the elementary principles of the science.

The Practical affords numerous applications of the formulas deduced in the First Part together with thorough discussions of qualities and kinds of iron, methods of joining rods, or plates, and an extended treatise on Iron Piers and Foundations.

The Descriptive part is embellished with large plates, designed to aid the engineer in preparing working drawings. Thirty of the plates present general views, the remainder (98 in all) give the details.

The price of the work has been much reduced.

Lessons on Elementary Physics. By Balfour Stewart, LL. D. F. R. S. London: Macmillan & Co. For sale by Van Nostrand.

This is a bold experiment, and decidedly deserves to be a successful one. Nearly all our elementary works, even on mere *departments* of Physics, are extremely bad, especially the so-called "original" ones ; and those which have been translated from the French are little suited to the genius of this country—however excellent they may be in France—while they are usually spoiled by inaccurate translation, or by clumsy and injudicious addition of a mere cobbling or patching kind.

The reasons are not far to seek. It is very rarely that we find in this country a genuine scientific man who can, like Faraday or Herschel, make himself easily intelligible even on difficult subjects to an ordinary reader; still more rarely that we find such a man to have paid such special attention to the merest elements of his subjects as to thoroughly understand them himself, which

ought to be regarded as an absolutely indispensable preliminary to his teaching them to others. Take, for instance, the question of the measurement of temperature in conjunction with the second law of thermodynamics, that very second law itself, or its connection with the equality of radiating and absorbing powers. Take even a simpler matter, the notion of a standard pound as a definite quantity of matter, not as something which shall be attracted by the earth with a certain force. Try all the elementary works in succession, and, if you are not driven mad by their inconsistencies and want of definiteness, endeavor to give in a clear, intelligible form the result of your studies on any such questions as those just mentioned. If you had no notion to begin with, you will have none, or worse than none, at the end; and even if you began with thorough knowledge, you would probably end helplessly confused, doubting the simplest and most obvious truths. But this is the way we do things at home; and hard, indeed, must be our British heads, which, after they have managed our "*As in præsenti*," etc., can plunge into this further chaos, and rise, as they often do, refreshed and invigorated by the struggle. A Frenchman, perhaps even a German, would perish in the attempt. But for them the path is made comparatively easy.

Nothing seems plainer than this, that he who has been ill-taught in the elements of his subject, however he may advance in knowledge (which is always a man's *own* work, whoever be his teacher) can hardly hope to understand these elements well enough to teach them to others. They have become to him a hateful thing, so he pushes on and avoids them as much as possible. Hence, that we may have really elementary works of a strictly scientific kind, we must have, not merely a genuine scientific man to write them, but one whose elementary instruction was good, or one whose strength has enabled him to get over its imperfections. These qualifications are certainly united in Dr. Stewart, for he had the late Principal Forbes for his teacher, and he is himself a man of quite exceptional powers, both in experiment and in reasoning.

It is scarcely possible to form a judgment as to the probable success of the present work. It is so utterly unlike anything to which we have been accustomed, that we can only say we never saw such a work, in English, at all events. Nothing so perfectly elementary, and yet throughout so intensely suggestive, have we ever met with. Even while reading the introductory chapters, we have several times laid down the book to follow trains of reasoning suggested by a single happy phrase that showed us something with which we had considered ourselves familiar, from a perfectly novel and interesting point of view. This, of course, will not strike the beginner, neither will it impede his progress; for it is not learned and abstruse disquisition or discussion, it is simply the clear vision of the writer.—*Extract from review in Nature.*

CASSELL'S TECHNICAL MANUALS: THE ELEMENTS OF PRACTICAL PERSPECTIVE. By ELLIS A. DAVIDSON. London and New York: Cassell, Petter, and Galpin. For sale by Van Nostrand.

The difference between professional and non-professional or artistic drawings may be summed up in the remark that the former are delineations in plane projection and the latter in perspective. The former is a correct representation to any scale on a single plane of what the actual object is; the latter, of what it appears to be. Instruction in the art of perspective drawing is one of the points in which our course of technical training is singularly deficient. There are comparatively very few engineering draughtsmen who can put an object correctly into perspective. We know of many instances in which, after draughtsmen had been engaged, and been requested to make a perspective drawing, they not only knew nothing whatever about it, but considered it not to come within their province. They appeared as much surprised at the request as if they had been expected to play the violin. It is true that engineers rarely make use of perspective drawing, although occasionally it is very advantageous to employ isometric perspective; but no architectural draughtsman can be considered properly qualified unless he is well up in perspective. The little manual on our table is intended as a sequel to one or two volumes formerly published on collateral subjects, and although it may be studied by itself, yet the wiser plan for the student, and the best in the end, will be for him first to master the "Linear Drawing" and "Projection," and then take up "Practical Perspective." The name of Mr. Davidson as the author of numerous volumes of Cassell's series is too well known to need any further mention. He has done, perhaps, as much as any man to popularize scientific instruction, and place subjects which are sometimes of rather an abstruse and complicated nature within the limits of the attainment of any person of average intelligence. Nearly every one now learns drawing, and every one who learns drawing ought to learn perspective. Whoever intends doing so cannot find a better medium for acquiring that knowledge than the volume under notice. Attention to the text and the reproduction on a large scale of the diagrams, are all that is needed to enable the student and the amateur to become thoroughly conversant with the subject.—*The Engineer.*

THE LIFE OF ISAMBARD KINGDOM BRUNEL, CIVIL ENGINEER. By ISAMBARD BRUNEL, B. C. L., Chancellor of the Diocese of Ely. London: Longmans, Green & Co., 1870.

In undertaking such a labor as that of placing on record the life of the great engineer and man of genius, a natural course for his son and biographer to have adopted, would have been to tell the whole story in his own language. With materials so rich for collation and reference, with every inducement that respect and love could offer, to linger over and transcribe in polished language the voluminous records of a vastly busy life, are opportunities afforded to few; the temptation so offered, we believe, few would resist. The first impression conveyed on glancing through this long biography, is that all thanks are due to the author for keeping in the background as much as possible, and giving all prominence to the subject of the memoir; we say this in no disparagement of the biographer, for he writes well; but the narratives he has ably strung together could not have been improved, and would assuredly have been marred had the old writings been revised and modified.

We have seldom read any book in which the interest is so sustained from first to last; we have never read one in which the man and his works are so strikingly portrayed, and that by himself; perhaps the reason of this is that he never imagined his writings would ever come under the public

eye; but they take the reader back to the middle ages of engineering, and tell him minutely the story of nearly all the most important works that have been planned during the past half century.—*Engineering.*

EXPERIMENTS ON THE MECHANICAL AND OTHER PROPERTIES OF STEEL; made at her Majesty's Dockyard, Woolwich. By a Committee of Civil Engineers. London: Adams, Brothers. 1870.

The results of these experiments, the first part of which is dated in 1868, are now in a printed form. They are chiefly tabular, and bound up in one volume.

The committee under whose superintendence the experiments have been carried out by Mr Kirkaldy, and collected from other sources, consisted of Messrs. W. H. Barlow, George Berkley, John Fowler, Douglas Galton, C.B., and J. Scott Russell. Mr. Berkley acted as secretary, and Mr. W. Parsey as assistant secretary. The contributors to the fund wherewith the expenses were met were Messrs. Bessemer & Co., John Brown & Co., the Barron Hematite Steel Company, the Bolton Iron and Steel Company, Charles Cammell & Co., Krupp & Co., Lloyds, Fosters & Co., the Monkbridge Iron and Steel Company, Naylor, Vickers & Co., and T. Turton & Sons. The arrangements were made to test the resistance of steel to tension, compression, transverse strain, and torsion. The second part relates to experiments on tension and compression carried out at Woolwich Dockyard, by permission of the Admiralty. The work contains experiments also on riveted joints, and a chemical analysis of certain bars, whose elasticity and ultimate strength are also given.—*The Engineer.*

ESTIMATES AND DIAGRAMS OF RAILWAY BRIDGES FOR TURNPIKE, PUBLIC, AND OCCUPATION ROADS, IN THE EMBANKMENTS OF DOUBLE OR SINGLE LINES, AND CUTTINGS OF DOUBLE LINES, WITH FORMULA FOR CALCULATING QUANTITIES IN SKEW STRUCTURES, ETC.; ALSO CULVERTS OF VARIOUS DIMENSIONS, AND STATION BUILDINGS. By J. W. GROVER, Member of the Institute of Civil Engineers. Second edition, enlarged. London: E. & F. N. Spon. For sale by Van Nostrand.

However great a genius a man may be, or whatever power of originality he may possess, it is rarely worth his while to neglect the value of precedents. In fact, in ordinary routine work there is scarcely any room for originality, unless experiments be made with untried materials. There is such a number of examples cut and dried, that research is the only thing needed to enable any engineer of ordinary intelligence to make a decent design for a railway bridge or viaduct. The carrying out of the design is another matter; but, provided the foundations be good, and proper superintendence be exercised over the work, there is not much fear of any difficulties arising. In the compilation of drawings before us there is an abundance of examples of bridges, culverts, and stations, all drawn to scale with figured dimensions, so as to leave scarcely anything for the engineer to do but to make a fair copy of any particular one that will suit his purpose. Throughout the volume two prominent descriptions of over-bridge designs in cuttings are selected for illustration, one in which there is a centre arch with two side arches, and the other in which the side arches are replaced by straight back wing walls. The latter type is the one we prefer in all instances in which there is any doubt about the character of the foundations. When the excavation runs through loose stuff it would be impossible to found the side arches so near the surface of the ground. It is questionable whether there is any real utility in repeating drawings in cases where the difference in depth of cutting is only a couple of feet. For over-bridges in embankments, splayed wing walls are of course adopted, although we cannot say we admire Mr. Brunel's system of construction. The drawings of the stations, although most of them are on a small scale, are likely to prove of great use, especially to engineers who are frequently required to design small stations, and are not very well up to architects' work. A second edition of Mr. Grover's book proves that it has been appreciated, and it will be found a handy volume for reference. The plates are carefully and clearly lithographed, and attention has been evidently bestowed upon the printing, lettering, and figuring dimensions, points which are often neglected in works of this description.—*Engineer.*

A REPORT ON BARRACKS AND HOSPITALS WITH DESCRIPTIONS OF MILITARY POSTS. By JOSEPH K. BARNES, Surgeon Genl. U. S. Army. Washington: Government Printing Office.

This is a quarto of about 500 pages, illustrated with many fine lithographs. It is in much better style than the average of Government scientific reports.

The pages look attractive even to the unmilitary reader, and, considering the reputation of the author, it is certain that the book will prove a valuable addition to the literature of military science.

A CLASS BOOK OF INORGANIC CHEMISTRY WITH TABLES OF CHEMICAL ANALYSIS AND DIRECTIONS FOR THEIR USE. By D. MORRIS, B.A. London: Geo. Philip & Son. For sale by Van Nostrand.

This compact little volume contains just that brief outline of chemical science which is so often needed by those who need to refresh their memories occasionally with the leading principles. The hints on qualitative analysis and the table of blowpipe reactions will prove valuable to any practical man. To the travelling scientific student, who is obliged to economize in the matter of bulk and weight, and who yet needs a neat compend of chemistry, both theoretical and practical, this little volume of 150 pages will prove of essential value.

MANUAL OF QUALITATIVE ANALYSIS. BY ROBERT GALLOWAY, F. C. S. Fifth edition, xxi. and 415 pp. London: John Churchill and Sons. For sale by Van Nostrand.

Of the various manuals of Qualitative Analysis now in use, none is more deservedly popular than the work of Professor Galloway. Much of this success is doubtless due to the painstaking care with which the author has sought in successive editions to reduce the operations of Qualitative Analysis to a more methodical and systematic process. The present edition is in great part rewritten, and much new and original matter has been incorporated. More systematic methods for separating the alkaloids are given, together with many additional reactions for their individual discrimination. The processes for detecting the poisonous metals in presence of organic matters are also

much improved. A description of Bunsen's neat and expeditious flame reactions is likewise a new feature in the book. The delicacy and certainty of these reactions ought undoubtedly to lead to their more general adoption in our laboratories; even if their application is found to be limited, the lesson in neatness and dexterity in working to be acquired in their performance would prove invaluable to the student.

One of the characteristics of this book is its thoroughness, and the very example of this quality will not be lost upon the beginner. As an illustration of what we mean, we give the following extract from the introductory remarks on the province and scope of qualitative analysis:

The analyst, by means of re-agents, interrogates the substance to be analyzed as to what are its component parts; the reactions are the language in which the answer is returned. The student has therefore to learn the mode of questioning the substance, and the language in which the answer will be conveyed; in other words, he has to learn, not only what general and special reagents are to be employed, but the order in which they are to be applied, and also the reactions they produce with the bases and acid-radicals, before he can attempt to search for these bodies in substances. No amount of *reading or lecture-hearing* will furnish the student with this knowledge; he can only obtain it by making the experiments himself of the different bases and acid-radicals with the reagents. and "*he must always reflect, before the addition of the reagent, for what purpose he applies it, and what are the phenomena he intends to produce*" And the conditions indispensable for the production of correct and decisive reactions must be carefully observed, for a half knowledge in all departments of science is of little worth, but in chemical analysis it is worse than useless.—*Nature.*

A New Manual of Logarithms to Seven Places of Decimals. By Dr. Bruhns, Director of the Observatory and Professor of Astronomy at Leipsig Bernard Tauchnitz, Leipsig. For sale by Van Nostrand.

These tables have been carefully revised, and, accepting the statement of the preface, are exceptionally free from error.

The typography and arrangement are excellent.

The sines, tangents, etc., are given to the nearest ten seconds throughout the table, and to single seconds for the first six and last six degrees of the quadrant. The volume is of octavo size.

MISCELLANEOUS.

The St. Thomas and Porto Rico Telegraph.—The West India and Panama Telegraph Company(Limited)state that they have received advices that the submarine cable has been successfully laid between the islands of St. Thomas and Porto Rico, and will be immediately opened for public traffic. They add that the section between Porto Rico and Jamaica is being proceeded with.

Soft Solder.—It is often very convenient, and, in fact, sometimes necessary, to have soft solder which will flow at different degrees of temperature. Many instances occur in which jobs can not (in the country) be done by a professional jeweller, consequently the watchmaker is expected to do whatever nobody else can; and he must often run the risk of spoiling work by subjecting it to too intense a heat; whereas, if he had a little easy-flowing soft solder, there would be no danger.

From the following table you can easily prepare such as you wish—if only a little of some of the sorts; it will be found convenient:

No.	1.	1	part	Tin,	25	Lead—melts	at	580° F.
	2.	1	"	"	10	"	"	" 541
	3.	1	"	"	5	"	"	" 511
	4.	1	"	"	3	"	"	" 482
	5.	1	"	"	2	"	"	" 441
	6.	1	"	"	1	"	"	" 370
	7.	1½	"	"	1	"	"	" 334
	8.	2	"	"	1	"	"	" 340
	9.	3	"	"	1	"	"	" 356
	10.	4	"	"	1	"	"	" 365
	11.	5	"	"	1	"	"	" 378
	12.	6	"	"	1	"	"	" 381
	13.	4	"	"	4	"1 pt.	Bism'th	320
	14.	3	"	"	3	"1 "	"	310
	15.	2	"	"	2	"1 "	"	292
	16.	1	"	"	1	"1 "	"	254
	17.	1	"	"	2	"2 "	"	236
	18.	5	"	"	3	"3 "	"	202

No. 8 is the common tinsmith solder. No. 7 is the most fusible, unless bismuth be added. No. 18 will melt at 122°, by the addition of 3 parts of mercury. The most convenient form for using soft solder is to have it in wire. It is very easy to have it in that form; for when you have it melted in a ladle, in pouring it out on a flat iron or stone you must trail it—that is, draw your ladle along so as to flow out on the stone a thread of metal. With a little practice you cannot but succeed. Any of these alloys will flow with the ordinary soldering fluid.

Another convenience for soft soldering is not as much used as it might be, and would save injury to many a job; that is, a soldering iron, the same as a tinsmith's, only minuter. A piece of copper wire, an inch long and ¼ in. thick, filed away almost to a point, with a wire handle about 4 in. long, terminated by a bit of wood or cork. In using, heat the copper in the lamp flame by laying it across something, to save time, and when hot enough to melt the solder, touch the end into your pickle, which will brighten it: then touch it to a bit of solder, and it will instantly take it up. Then you can apply it at any point you wish, without heating the balance of the article in hand.—*Am. Horological Journal.*

Conducting Wires for Military Telegraphs.—The conducting wires of the military telegraphs which are used in the French army are so made as to be capable of resisting the trampling of horses and the crushing of wheels of the heaviest vehicles on common roads, but not that of artillery. Of late the French military authorities have paid great attention to military telegraphy, and before the war broke out they instituted a series of experiments on it at the camp at Chalons. Lines of wire were laid down in every direction on the public roads, and allowed to remain there day and night for whole weeks at a time, subject to all the passing traffic of horses and vehicles of every description, and to every change of weather, and it was found that, notwithstanding all these trials, messages could be transmitted with perfect accuracy and facility. The wire with which the experiments were tried, and which is used at this

moment by the French, is simply a line about one-fifth of an inch in thickness. It is a sort of a miniature submarine cable, which, being protected by a strong covering, is capable of resisting the dangers of rupture and crushing, and, to the eye of the uninitiated, presents the appearance of a thin tarred rope. In the centre of it 4 threads of copper, twisted together, form the metallic portion which is to conduct the electric fluid, or rather the electric motion. A final spiral of cotton surrounds them; over this is a thin coating of india-rubber, and the whole, wrapped in a species of vegetable hair, is fastened together and held by two ribbons of impermeable stuff. The cable is wound round enormous bobbins, ranged in military line, 8 and 8, on special vehicles, and is wound off as the army advances. When it is to be used one of the telegraphers fixes it on the ground by double nails, resembling hair pins. But each carriage contains only 1,100 or 1,200 yds. of cable, and it frequently happens that the message has to be sent to a greater distance. In this case it becomes necessary to unite the cable already laid with that contained in another carriage. The telegrapher, therefore, cuts the ends of each wire, lays bare the copper thread, untwists them in a delicate manner, and then plaits the strands of each cable together, or as sailors would say, he splices them; and this operation can be repeated as often as need be. As, in the French service, the rule is to send a train of 8 carriages laden with cable with each brigade or division of the army, it it evident that telegraphic communication can be carried on to no greater distance than about 10,000 yds., or not quite two miles. In a great battle, extending over several miles, and in operations such as those now going on, extending over a large area—say 40 or 50 miles—these field telegraphs would have to be very numerous in order to keep up communication with all points of the line.

Drying of Wood.—The following is substantially the subject-matter of a lecture before the meeting of the Polytechnic Society of Munich in reply to the query, What means are applied at Munich for the proper drying of wood required for architectural, joiner's, and other purposes? The author enters, first, into a series of particulars relating to the very varying quantity of water (moisture and juices) contained in various kinds of wood at different periods of the year, from which it appears that, according to Dr. Hartig's experiments, woods (trees) generally contain, during the winter months, about an average of 50.7 per cent. of moisture; in March and April, about 46.9 per cent.; in May, June and July, about 48 per cent.; while up to the end of November the quantity of moisture increases but little. Air-dried wood (timber) contains from 20 to 25 per cent. of water, and never less than 10 per cent. Wood which, by being artificially dried, has been deprived of all moisture, is thereby entirely altered as regards its cohesive strength—it becomes brittle, loses its elasticity and flexibility. In order to dry all kinds of timber by artificial means, so as to preserve the essential physical structure, and, thereby, the good properties of the wood, the drying should be effected slowly, and the temperature to which the timber is submitted should be moderate to begin with, and care should be taken not to eliminate all the water. The author enters into details, illustrated by engravings, on the best means of drying timber on the large scale, and states that small pieces of wood, such as are intended for joiners and furniture-makers, may be readily and efficiently dried by being placed in dry sand, and then heated to 100 deg. The sand acts in the manner of an absorber of the moisture, as well as a diffuser of the heat.

New Japanese Mint.—Following the example of Hong Kong, the Japanese are about to have a mint of their own. It will be recollected that some time since, Hong Kong built a mint and fitted it up in a first-class style at a cost of over £100,000; and, but for that most conservative power called "vested interests," there is very little doubt but that the Hong Kong mint would have been a successful undertaking. However, it was stopped, to the manifest loss of the whole community, from the Straits Settlements to Japan. The Japanese Government bought the machinery, and it was transferred to Osaka, and placed in a very handsome cut-stone building, expressly constructed for the purpose, where the operation of coining will commence in 1871. The new coinage is to consist of gold 10, 5, and 2½ dollar pieces; silver dollars, and 50, 20, and 5 cents; and copper, 1 and ½ cents, and 1 mill—this latter being probably the smallest modern minted coin. The dies were from Japanese designs, and were sent out from England; but, owing to the "reverse" in each case not proving very effective, some alterations thought judicious have been introduced. On the obverse of the gold coins will be the Japanese dragon in the centre, tied in an inextricable knot, surrounded by the value and date in Japanese. The reverse has in the centre the arms of Japan—the round red "pellet"—above and below which are the flower badges of the Mikado. On either side of the arms are branches of the shrubs that bear the flower—emblems of Japan, and near the two "waveless" flags of the Mikado. The silver coinage is similar on the "obverse," but the "reverse" has the "pellet" in the centre, surrounded by rays towards the margin, in which the crests or badges of the Mikado appear with the wreaths before mentioned. The copper coins are similar to the above, with smooth-skinned dragon instead of a scaly one. It will thus be seen, says the "European Mail" of November 17, that the fancy of the Japanese for dragons and flags without waves has been fully indulged; while, at the same time, the coinage will be handsome and striking, and far in advance of the Hong Kong mintage. With respect to the future working of the undertaking, the work before the officials is undoubtedly heavy, as a population of 40,000,000 of people will have to be supplied; but the machinery is all of the best construction, and Captain T. W. Kinder is a man of considerable acumen, and has had some years Eastern experience, having occupied a similar position at Hong Kong mint. The melting department is furnished completely with the well-known manufactures of Morgan's "Patent Plumbago Crucible Company," Battersea. Some regret is felt that the building is so far inland, and on such a dangerous river as is Osako; Hiogo or Yokohama, therefore, would have been much preferred as the site.

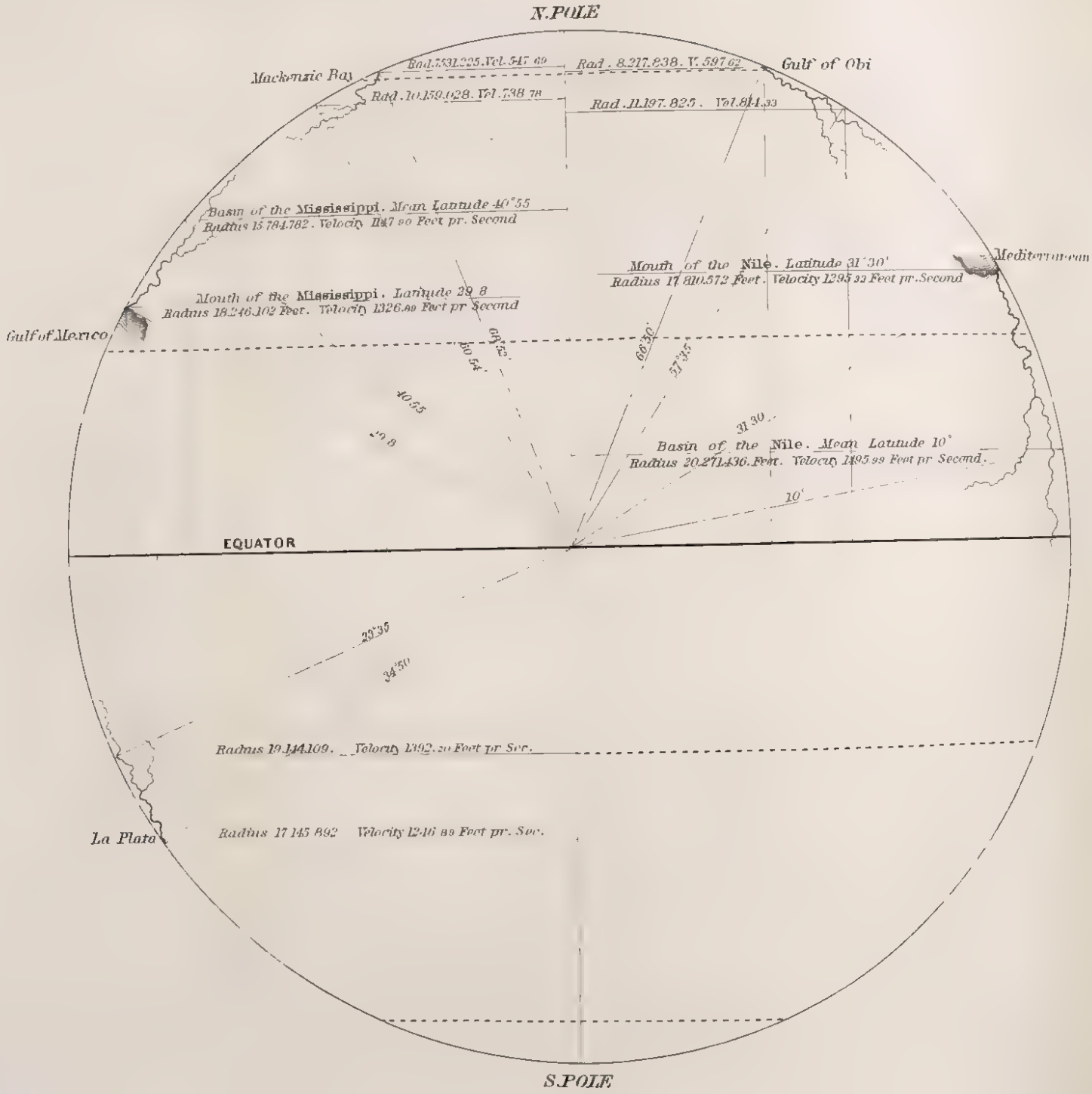
Western Australian Sleepers.—Considerable shipments of sleepers continues to be made at Freemantle, Western Australia, for Indian railways. Western Australia has no railways of her own, but is talking about them.

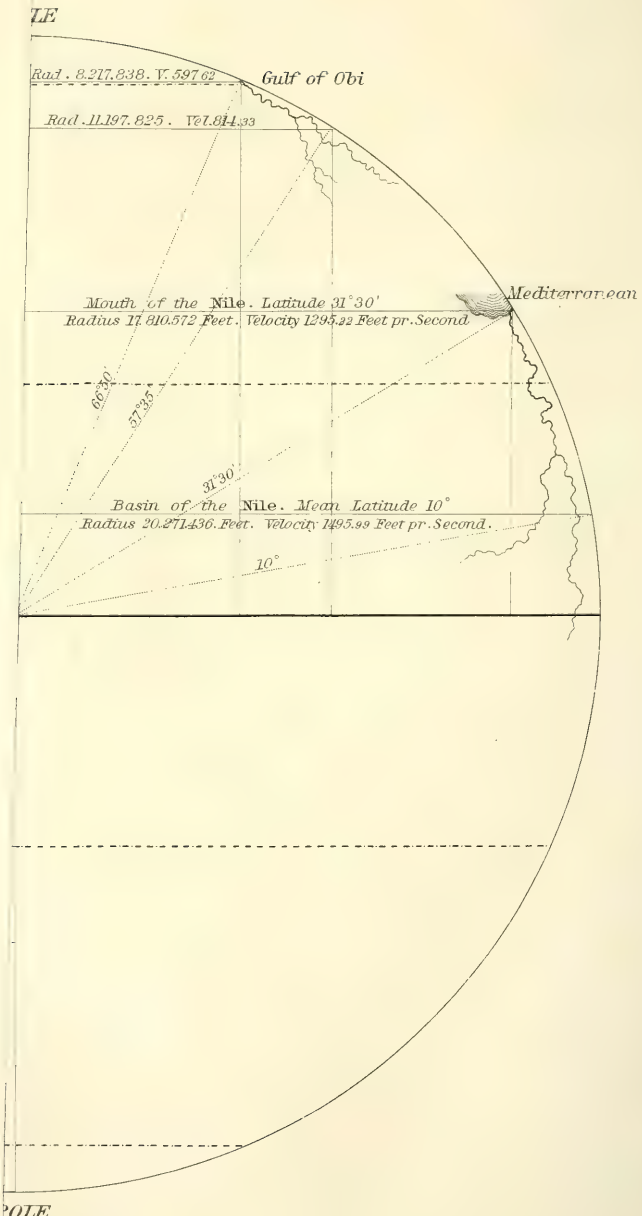
SECTION OF THE EARTH

Represented as a perfect Sphere.

Mean diameter 7912 in statute miles.

Scale 1300 miles-1 inch.

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Rad . 8.217.838. V. 597.62
Gulf of Obi
Rad . 11.197. 825 . Vel. 814.33
Mouth of the Nile . Latitude 31°30'
Radius 17.810.572 Feet . Velocity 1295.32 Feet pr. Second
Mediterranean
60°30'
37°35'
31°30'
Basin of the Nile. Mean Latitude 10°
Radius 20.271.436. Feet. Velocity 1495.99 Feet pr. Second.
10°
POLE

VAN NOSTRAND'S
ECLECTIC
ENGINEERING MAGAZINE.

No. XXVIII.—APRIL, 1871.—Vol. IV.

SOLAR HEAT—ITS INFLUENCE ON THE EARTH'S ROTARY VELOCITY.

BY CAPTAIN JOHN ERICSSON.

From "Engineering."

(*See Frontispiece.*)

Laplace's demonstration showing that the axial rotation of the earth is not affected by atmospheric currents and similar motions caused by solar heat, has been accepted by physicists as incontrovertible. The German mathematician, Dr. Mayer—celebrated for his demonstration establishing the equivalent of heat—says in a discourse on that branch of celestial mechanics which relates to the effect produced by contrary atmospheric currents: "The final result of the action of these opposed influences is, as regards the rotation of the earth, according to well-known mechanical principles=0; for these currents counteract each other, and therefore cannot exert the least influence on the axial rotation of the earth. This important conclusion was proved by Laplace." "The same" he adds, "holds good for every imaginable action which is caused by the radiant heat of the sun, or by the heat which reaches the surface from the earth's interior, whether the action be in the air, in the water, or on the land. The effect of every single motion produced by these means on the rotation of the globe, is exactly compensated by the effect of another motion in an opposite direction; so that the resultant of all these motions is, as far as axial rotation of the globe is concerned = 0." I propose to show that this conclusion is fallacious, and that the sun's radiant heat develops forces capable of diminishing perceptibly the earth's rotary velocity. And that unless the retarding influences of solar heat, the existence of which I am going to establish, are counteracted by some cosmical force of which we have no knowledge, the earth's rotary velocity will be considerably reduced in the course of time.

There are two classes of force produced by solar heat, capable of retarding the axial rotation, differing, however, entirely as regards ultimate results. The first class includes animate exertion, mechanical force produced by heat developed by the combustion of organic substances, and the resistance of abraded solid matter transferred from its original position, by the waters of rivers flowing towards the equator. The forces thus enumerated, it will be shown, retard the rotary velocity of the globe in all cases when they remove weight to a greater distance from the axis of rotation, *i.e.*, expand the circle of gyration, thereby diminishing the number of revolutions performed in a

given time, Obviously the vis viva of the rotating mass will remain undiminished, as the centre of gyration is merely removed to a greater distance from the axis of rotation. Accordingly, the axial rotation, though checked, can never be stopped by the class of retarding influences thus pointed out. The second class, however, which comprises the retardation produced by the atmospheric air during its course from the polar to the equatorial regions; and the retardation caused by the waters which flow towards the equator to restore the quantity lost by the powerful evaporation within the tropics, not only diminishes the rotary velocity, but, at the same time, deprives the earth of so great an amount of vis viva, that the axial rotation must ultimately cease, unless some exterior compensating force exists, a supposition at variance with the principles of mechanics.

Let us now briefly examine the nature of the retarding influences of the first-named class, which, as stated, are unattended by any loss of the earth's vis viva, namely, animate force and mechanical energy, resulting from the combustion of organic substances when expended in raising weight to remain permanently in an elevated position; and the retardation caused by solid matter carried towards the equator. Before entering on this examination, it will be instructive to test by some familiar illustration, the correctness of the assumption that "every imaginable action affecting the rotation of the globe, is exactly compensated by the effect of another motion in an opposite direction." A great variety of instances might be mentioned in which the development of mechanical energy, productive of heat, counteracts the rotary motion of the earth, and deprives it permanently of a certain amount of vis viva. Suppose, for instance, a locomotive train weighing 400 tons, to be started from the western terminus of a railway running from west to east. Suppose also that when this train has acquired a velocity of 50 ft. per second, it encounters another similar train which is at rest. The result of such an encounter, in a dynamic point of view, is now well understood. Apart from a small amount of energy absorbed in overcoming the cohesive force of the materials fractured by the concussion, the encounter will develop an amount of heat corresponding with the vis viva of the arrested train. It scarcely needs explanation that in putting the train in motion from the terminus eastward, the rails, *i.e.*, the surface of the earth, will, in consequence of the adhesion between the wheels and the rail, be pushed westward; hence in a direction contrary to the earth's rotation. The amount of dynamic energy which the train thus imparts to the earth in an opposite direction to that of rotation, may be readily ascertained by multiplying the arrested weight by the height necessary to produce a velocity of 50 ft. per second, namely, 39 ft.; hence $400 \times 2240 \times 39 = 34{,}944{,}000$ foot-pounds. Deducting the small amount of energy which favors the earth's rotation called forth by the rolling friction and adhesion of the wheels of the stationary train, during the short retrograde motion attending the concussion, it will be found that the earth loses an amount of vis viva of 34,000,000 foot-pounds. The assumption of Dr. Mayer, based on the theory of Laplace, that the resultant of all imaginable motions as regards the earth's axial rotation, is $= 0$, we have thus proved to be untenable. It is not intended to question Laplace's conclusion as regards the existence of a compensating effect; he was mistaken only as to its nature, a mistake, however, of paramount importance, as we have shown that the compensation for the lost energy, in the case presented, is merely the generation of a certain amount of heat which in less than three hours after the concussion, if the sky be clear, radiates into space, leaving the earth minus 34,000,000 foot-pounds of vis viva. Lest the circumstance should be overlooked, it will be well to call attention to the fact, that the retardation thus established is the result of solar energy stored in the combustibles of the locomotive furnace. Numerous other instances might be mentioned in support of the assertion that the earth is subjected to retarding influences and loss of vis viva, by mechanical motions on the earth's surface which result in the production of heat. But all these are insignificant compared with the stupendous amount of retardation caused by the conversion of mechanical energy into heat, within the atmospheric currents circulating between the equatorial and polar regions. In connection with this fact, it will not be out of place to remark, that

our knowledge of the convertibility of mechanical energy and heat—in other words, the convertibility of mechanical and molecular energy—has completely upset Laplace's illusory demonstration on which physicists have based their assumption that the rotary velocity of the earth cannot be affected by the sun's radiant heat.

Let us now examine, separately, those forces produced by solar heat which tend to check the earth's rotary velocity by removing weight from the axis of rotation, *i.e.*, expanding the circle of gyration, and those which occasion a diminution of the rate of axial rotation without disturbing the balance of the rotating mass. The first class : Animate or muscular energy, and the force generated by heat from the combustion of organic matter, controlled by the human mind, both resulting indirectly from the sun's radiant heat. That the hand and intellect of man have caused a disturbance of the position of the earth's centre of gyration, will be deemed a startling assertion ; yet it cannot be controverted in view of the following facts. The millions of tons of matter contained in the Pyramids, removed to a greater distance from the axis of rotation by the muscular exertion of the ancient Egyptians, disturbed the previous balance of the rotating mass, causing a tendency to check the earth's rotary velocity, and to increase the length of day. Nor can it be questioned that if London had not been built, and if the building materials of Paris yet remained in the Catacombs, the sun would rise earlier than it now does, though the difference would be small beyond computation. The aggregate of the weight removed from below, and piled above the crust of the globe by the hand of man, is, however so great, that figures are competent to express the extent of the consequent retardation of the axial rotation, while the divisions of our common instruments for measuring distance are sufficiently minute to indicate the expansion of the earth's circle of gyration, caused by the transfer of matter under consideration. A first-class modern city, for instance, contains upwards of 100,000 houses; each house weighs on an average 400 tons, hence the total weight removed from below the surface to a considerable height above the earth, exceeds 40,000,000 tons, a mere fraction compared with the weight of the whole of human habitations and other structures raised above the surface of the earth by human effort, besides the weight of minerals which, during centuries, has been removed to an increased distance from the axis of rotation, by animate exertion and by mechanical force controlled by intellect.

An element of greater importance, connected with the first class of retarding influences, produced by the sun's radiant heat, next claims our attention, namely: the solid and sedimentary matter detached by the abrasion of rain water and afterwards conveyed by the currents of certain rivers, to a position nearer the equator; hence removed to a greater distance from the axis of rotation. The question whether any estimate can be made of the aggregate weight of matter, the original position of which is being changed during definite periods, by the cause referred to, is by no means so difficult to answer as might appear without due consideration. It is true, we do not know what quantity of water or sediment is carried towards the equator by the several rivers; but we can compute with sufficient exactness the extent of the river basins. Accordingly, if we could establish a mean of discharge per square mile of some very extensive basin comprising all the varieties of climate and soil, the question could be satisfactorily answered. Fortunately one of the longest rivers on the globe, the Mississippi, which drains the greatest extent of surface with but one important exception, has been carefully surveyed by a corps of Topographical Engineers, under the direction of General Humphreys, by order of the United States Government. Not only has this great river been thus carefully examined, but its basin comprises every variety of soil and climate, its source being among snows, and lakes frozen during a greater portion of the year, while the outlet is near the tropics. How completely the Mississippi basin represents the average of the river systems of both hemispheres will be understood from this fact, that although the rain gauges at its northern extremities show only 13 in. for twelve months, those of the southern extremity reach 66 in.; with every possible gradation of precipitation in the intermediate space. In addition to this important circumstance, the basin covers 21 deg. of latitude and 35 deg. of

longitude, or 1,460 miles by 1,730 miles; hence comprising an area greater than the entire European Continent west of the rivers Vistula and Pruth. It may be confidently assumed, therefore, that the Mississippi basin represents the average discharge of water and sediment so nearly that calculations based thereon, applied to the river systems of both hemispheres —excepting some of the northern Asiatic and American rivers—will exhibit a general result differing but slightly from what would be established if all the rivers had been examined.

The elaborate report of General Humphreys to the Bureau of Topographical Engineers, Washington, shows that the average quantity of earthy matter carried into the Gulf of Mexico, partly suspended in the water and partly pushed along the bottom of the river by the current, amounts for each twelve months to 903,100 millions of pounds. This enormous weight of matter is contributed by numerous large branches and upwards of 1,000 small tributaries. The main distance along the streams, which the sediment is carried in its course to the sea, exceeds 1,500 miles. The distance which determines the amount of force tending to check the earth's rotation, is obviously shorter.

The maps of the Mississippi river basin accompanying General Humphreys' report, show that its centre is situated 7 deg. 10 min. west of the mouth of the main river, and 11 deg. 15 min. north of the same, in latitude 40 deg. 15 min. It will be found on inspecting the accompanying section of the earth, that agreeable to the stated latitudes, the centre of the Mississippi basin rotates in a circle of 15,784-782 ft. radius, and that its velocity round the axis of the globe is 1,147.90 ft. per second. The mouth of the river, it will also be seen, rotates in a circle of 18,246-102 ft. radius, with a circumferential velocity of 1,326.89 ft. per second. Comparing these velocities we ascertain that an increased circumferential velocity of 178. 99, say 179 ft. per second, is imparted to the water and to the sedimentary matter which it conveys during the course from the centre of the basin to the mouth of the river. As before stated, the annual discharge of earthy matter at the mouth of the river is 903,100 millions of pounds. The centre of the basin, lat. 40 deg. 15 min., being 2,461,320 ft. nearer to the axis of rotation than the mouth of the river in lat. 29 deg. 0 min., it will be found that the increase of rotary velocity as already stated is 179 ft. per second—a rate acquired by a fall of 500.6 ft. The elements are thus furnished for determining with exactness, the amount of retardation attending the change of position of the abraded matter during its transfer from the basin to the mouth of the river. Multiplying 903,100 millions by 500.6 we ascertain that the counteracting force exceeds 452,000,000,000,000 foot-pounds annually $= 452 \times 10^{14}$ foot-pounds in a century. The earth's present vis viva being $18\text{-}875{,}361 \times 10^{22}$ foot-pounds (to be demonstrated at the proper time), it is easy to calculate that the retardation occasioned by the stated reacting energy called forth by the sedimentary matter which is carried to the ocean by the Mississippi, will amount to $\frac{36}{100{,}000}$ of a second in a century. In view of this small fraction of time, it will be well to remind the reader that the retardation of the earth's rotary velocity, inferred from the apparent acceleration of the moon's mean motion, now generally admitted by astronomers, is somewhat under 12 seconds in a century. Insignificant as this retardation appears to be, it calls for a constant reacting force of 4,55-000,000,000 foot-pounds per second, as will be shown in the course of our investigation. Dividing this amount by the adopted standard of a horse power, viz., 550 foot-pounds per second, it will be found that a constant energy represented by 827,000,000 horse power, exerted in a contrary direction to that of rotation, is necessary to check the rotary motion to the extent mentioned, viz., $\frac{12}{86400} = \frac{1}{7200}$ of a revolution in the course of a century. Accordingly, 720,000 years, nearly, will elapse before one entire revolution shall have been lost, notwithstanding the existence of a constantly retarding force of 455,000 millions of foot-pounds per second. We can readily ascertain the aggregate of this force during the long period mentioned, if we multiply the same by the number of revolutions of the earth per annum, and the number of seconds for each revolution; thus, $455 \times 10^9 \times 365.24 \times 86{,}400 \times 720{,}000 = 103{,}379{,}867 \times 10^{17}$ foot-pounds. By dividing this amount of energy in the earth's vis viva, $18{,}875{,}361 \times 10^{22}$ foot-pounds, we ascer-

tain that the stated enormous retardation overcome in the course of 720,000 years, amounts to only $\frac{1}{18258}$ of the present rotary vis viva of our planet. Probably no other mode of presenting the subject could give so clear an idea of the vastness of the mechanical energy of a sphere 8,000 miles in diameter, whose specific gravity is $2\frac{1}{4}$ times that of granite, revolving at a rate of one revolution in 24 hours. Returning to the retardation produced by the Mississippi, let us bear in mind that the precipitation which causes the abrasion of the solid matter and the currents by which it is conveyed is the direct result of the sun's radiant heat.

With reference to the Tables given on pages 116 and 117, it should be stated, that the amounts of the retarding force entered in the last two columns, are based on the data furnished by the examinations of the great Western river, viz. : that 1 lb. of solid matter and 1,350 lbs. of water, per second, are carried to the sea for every 40.08 sq. miles of basin. All other particulars necessary in computing the retarding energy exerted by each river, separately for the two hemispheres, will be found in the Tables. The mode adopted in determining the area drained by each river and tributaries, will be readily comprehended by the following explanation. The extent of the several river basins, 136 in all in both hemispheres, have been ascertained from the best maps extant ; the boundaries of the basin being determined by drawing a line on the map dividing the territory equally between the source of each river and tributaries, and those of adjoining basins. The boundaries being thus defined, the areas have been calculated in English statute miles ; the latitude and longitude of the centre of each basin being determined at the same time. By supposing the earth to be a perfect sphere 7,912.41 miles in diameter, according to Sir John Herschel's determination, the calculations have been rendered extremely simple. This will be seen by reference to the annexed section of the earth, which contains all the elements for computing the rotary velocity of the centres of the river basins, and of the outlets of the rivers. These velocities have been entered in the Tables, separately for each river basin; also the retardation, expressed in foot-pounds per second, caused by the increase of rotary velocity during the transfer of the sedimentary matter from the centre of the basin to the mouth of the river. The last column of the Tables contains the result of computations of the amount of retardation occasioned by the volume of water which conveys the sedimentary matter, a subject to be considered under a separate head hereafter.

It should be observed, that owing to their trifling influence on the earth's rotation, and in order to save space, all the English and Scotch river basins whose sediment is transferred in the direction of the equator, have been entered together in the Tables ; the rivers of Ireland likewise. But in computing the loss or gain of energy, each river basin has been calculated by itself ; the amount of retardation entered being the result of the whole quantity of sediment transferred towards the equator by the several small basins referred to. Accordingly, the area which is entered in the Table, represents the total. The river basins of Sweden and Norway being very numerous and unimportant, have also, in some districts, been entered together in the Tables like those of Great Britain. Finally, the narrow coast districts, in both hemispheres, have been computed and entered in the Table in a similar manner. See Tables on page 342.

The quantities of sedimentary matter discharged by the Indus, Ganges and Brahmapootra, being known with tolerable accuracy from actual observation, have not been computed according to the standard furnished by the Mississippi, which, as before stated, is 1 lb. of sediment per second for every 40.08 sq. miles of basin. Besides, local circumstances, such as the heated waters and profuse evaporation of the Bay of Bengal, and the powerful condensation attending the close vicinity of the Himalaya Mountains, render the Ganges quite exceptional.

[TO BE CONTINUED.]

PRACTICAL engineers about New York are much exercised by the reputed performance of Paine's Electro-Magnetic Engine at Newark. It apparently does the work of a 2-horse power engine, though driven by only three Bunsen battery cups. Many electricians believe in it. Engineers naturally doubt it.

RIVERS FLOWING TOWARDS THE EQUATOR. (*See "Solar Heat," page 337.*)

NAME OF RIVER OR DISTRICT	River Basin.							Mouth of River.				Retardation.	
	Area.	Latitude of centre.		East of outlet.		West of outlet.		Rotary velocity.	Latitude.		Rotary velocity.	Incr. of velocity	By Sediment.	By Water.
	Square miles.	Deg.	M.	Deg.	M.	Deg.	M.	Feet per second.	Deg.	M.	Feet per sec'd.	Feet per sec'd.	Foot-pounds per sec'd.	Foot-pounds per second.
EASTERN HEMISPHERE.														
Anadir	119 200	65	50	..	..	1	35	622	64	30	654	32	47 680	64 368 000
Rivers, N. W. coast Sea of Kamtschatka	52 000	61	42	..	10	..	..	720	60	45	742	22	9,828	13 267 800
Penshina	50 100	63	20	..	20	..	..	681	61	46	719	38	28,256	38 145 600
Rivers, west coast Sea of Okhotsk	32 600	62	00	..	..	..	05	713	61	20	729	16	3 260	4 401 000
Yama	15 500	60	45	..	..	1	30	742	59	40	767	25	3 786	5 111 100
Tawi and Kowa	13 300	60	25	..	..	..	10	750	59	40	767	17	1 503	2 029 050
Ochola	21 500	60	48	..	..	..	40	741	59	45	765	24	4 838	6 531 300
Ud	25 400	55	25	..	..	2	35	862	55	20	864	2	40	54 000
Toumen	20 000	43	20	..	..	..	15	1105	42	55	1112	7	385	519 700
Yaloo	21.200	41	10	1	05	..	..	1144	40	10	1161	17	2 396	3 234 600
Sira Muren	78 700	42	40	..	..	1	06	1117	40	50	1149	32	31 480	42 498 000
Chanton	29 800	41	00	..	..	..	30	1146	39	10	1178	32	11 920	16 092 000
Pei-ho	124 000	38	40	.	..	2	45	1186	38	25	1187	1	48	64 800
Min Kiang	25 400	26	20	..	..	1	15	1362	26	00	1364	2	40	54 000
Han Kiang	26 200	24	18	..	05	..	..	1384	23	20	1395	13	173	233 550
Tche Kiang	144 400	24	10	..	..	3	50	1386	22	53	1399	13	9 530	12 865 500
Hoang Ho	448 200	36	50	..	..	10	25	1216	33	45	1263	47	386,797	522 175 950
Sang Koi	76 300	22	40	..	..	2	28	1402	20	32	1423	21	13.143	17 743 050
Coast Rivers, Gulf of Tonquin	26 000	20	12	..	..	1	50	1426	20	00	1427	1	10	13 500
Menam Kong	329 500	16	38	..	..	3	15	1455	10	05	1496	41	216 399	292,138,650
Irawady	205 000	22	35	..	..	..	30	1403	16	10	1459	56	251 125	339 018.750
Brahmapootra	379 000	29	12	1	05	..	..	1326	22	00	1408	82	5 187 040	7 002 504 000
Ganges above Ghazepoor	187 100	27	25	..	..	5	25	1346	22	00	1408	62	1 463 818	1.976 154 300
Ganges below Ghazepoor	237 200	27	30	..	..	5	12	1347	22	00	1408	61	2 694,633	3 637 754.550
Khaladaing	27 400	21	15	..	..	..	20	1416	20	30	1423	7	527	711 450
Braming and Coyle	31.000	22	12	..	..	1	26	1406	21	15	1416	10	1,209	1 632,150
Mahanuddy	41 300	21	02	..	..	3	55	1418	20	28	1423	5	403	544,050
Rivers N. W. coast of Bay of Bengal	24.000	19	15	..	..	..	32	1434	18	20	1442	8	600	810 000
Godavery	133.000	19	35	..	..	3	25	1431	16	50	1454	23	27 498	37.122 300
Kishna	104 900	16	45	..	..	4	35	1455	16	10	1459	4	656	885 600
Rivers west coast Bay of Bengal	8.300	15	45	..	..	..	18	1462	15	30	1464	2	13	17 550
Penaur	17.900	14	45	..	..	1	30	1469	14	35	1470	1	7	9 450

Palar	23 700	12	52	..	..	1	20	1481	12	40	1482	1	9	12 150
Cauvery	25 000	11	45	..	..	1	53	1487	10	55	1492	5	244	329 400
Tapty	23 600	21	15	2	50	..	..	1416	21	10	1417	1	9	12 150
Nurbudda	21 600	22	14	3	45	..	..	1406	21	48	1410	4	135	182 250
Sukernully	29.700	23	27	..	25	..	..	1394	22	30	1403	9	943	1 273 050
Jahu	48 300	26	25	2	20	..	..	1360	24	52	1378	18	6,110	8.248,500
Indus	346 300	33	30	5	20	..	..	1267	24	00	1388	121	5 140 969	6.940 308 150
Helmund	124 000	32	42	3	25	..	..	1278	31	52	1290	12	6 975	9 416 250
Northern coast of Arabian Sea	93,000	26	30	1	00	..	..	1359	25	15	1374	15	8 184	11 048 400
North-east coast of Persian Gulf	66 000	29	00	..	45	.	..	1329	27	50	1343	14	5 049	6 816 150
Southern coast of Arabia	96 000	15	20	..	..	..	50	1465	13	50	1475	10	3 744	5,054,400
Euphrates and Tigris	282 100	35	05	..	..	4	35	1243	30	05	1314	71	555 525	749,958 750
Kour	95 400	39	55	..	..	3	32	1165	39	52	1166	1	37	49 950
Oural	126 300	50	04	2	01	..	..	975	47	02	1035	60	177 609	239.772 150
Don	195 400	48	56	1	48	..	..	998	47	06	1034	39	98 921	133,543 350
Emba district	37,800	47	50	3	00	..	.	1020	46	50	1039	19	5 330	7,195 500
Volga	557 700	55	00	..	..	..	10	871	46	10	1052	181	7 137,026	9 634 985 100
Kuban	34 600	44	50	2	55	..	..	1077	44	42	1080	3	121	163 350
Rioni	17 900	42	38	..	50	..	..	1118	42	15	1124	6	251	338 850
Syrian Mediterranean rivers	8 800	33	40	1	10	..	..	1265	33	22	1268	3	30	40 500
Jordan district	12 400	32	20	..	35	..	..	1285	31	48	1290	5	121	163.350
Schoon	12 000	47	40	..	15	..	..	1023	46	45	1041	18	1 518	2 049 300
Axon and others	23 600	47	32	2	00	..	..	1026	46	40	1042	16	2 360	3 186 000
Minder	9 900	47	40	1	35	..	..	1023	47	30	1026	3	35	47 250
Sarabat	8 300	48	22	1	15	..	..	1009	48	18	1010	1	3	4 050
Dnieper	181 000	51	25	..	..	..	33	947	46	40	1042	95	638 115	861 455 250
Bug and Indul	27 400	49	05	..	..	1	21	995	46	42	1042	47	23,646	31 922.100
Dneister	30 500	48	32	..	..	2	08	1006	46	20	1049	43	22 029	29 739 150
Maritza	23 700	42	00	..	..	..	22	1129	40	45	1148	19	3,342	4 511.700
Striman	13 000	41	28	..	..	..	30	1138	40	55	1148	10	507	684 450
Vardar	12 300	41	20	..	..	..	10	1141	40	32	1154	13	812	1.096 200
Drin	9 500	42	10	..	25	..	..	1126	41	40	1135	9	302	407 700
Donau	293 100	46	25	..	..	9	50	1047	45	15	1069	22	55 396	74 784 600
Tornea and Kemi district	41 700	67	20	..	..	..	05	585	65	52	621	36	21.111	28 499 850
Wester Botten	36 900	65	50	..	..	2	55	622	64	40	650	28	11.301	15 256 350
Wester Norrland	26 200	63	30	..	..	1	58	678	62	20	705	27	7.460	10 071 000
River Dahl district	20 300	61	16	..	..	2	00	730	60	35	750	20	3,172	4 282 200
Clara and Gotha Elv	16 700	59	40	1	45	..	..	767	57	48	809	42	11,506	15 533 100
Mälar district	9 400	59	45	..	..	1	10	765	59	25	773	8	235	317 250
Eastern part of South Sweden	5 800	56	55	..	..	1	00	829	56	15	844	15	510	688,500
Western part of South Sweden	6 600	57	30	..	42	..	..	817	56	40	835	18	835	1 127 250
Glommen and Lauven district	21 300	60	52	..	..	..	04	740	59	10	779	39	12,658	17 088.300
Southern part of Norway	9 500	59	18	..	..	..	15	776	58	10	801	25	2,320	3 132.000
Rivers east coast of Adriatic	17 200	43	50	..	20	.	..	1096	43	30	1102	6	241	325,350
Rivers discharging Gulf of Taranto and Ionian Sea	7 500	40	00	..	..	..	25	1164	39	30	1172	8	188	253,800
Western part of South Italy	11 900	41	15	..	30	..	..	1142	40	40	1152	10	467	630.450
Tiber	7.200	42	42	..	17	..	..	1116	41	45	1133	17	814	1,098,900

RIVERS FLOWING TOWARDS THE EQUATOR—*Continued.*

NAME OF RIVER OR DISTRICT.	River Basin.									Mouth of River.				Retardation.	
	Area.	Latitude of centre.		East of outlet.		West of outlet.		Rotary velocity.		Latitude.		Rotary velocity	Incr. of velocity.	By Sediment.	By Water.
	Square miles.	Deg.	M.	Deg.	M.	Deg.	M.	Feet per second.		Deg.	M.	Feet per sec'd.	Feet per sec'd.	Foot-pounds per sec'd.	Foot-pounds per second.
EASTERN HEMISPHERE.															
Arno and west coast of Central Italy	8 900	43	25	..	32	..	..	1103		43	00	1111	8	223	301,050
Etsch district	12 000	46	15	..	..	..	34	1050		45	00	1074	24	2 700	3.645 000
Po	28,100	45	25	.	..	3	10	1065		44	50	1077	12	1 412	1 906,200
Rhone	38 000	45	42	..	41	..	..	1061		43	25	1103	42	26,182	35 345 700
Ter and Slobregat	11 200	42	45	..	..	..	25	1115		42	40	1117	2	18	24 300
Ebro	33 200	42	06	..	..	2	20	1127		41	02	1146	19	4.681	6,319 350
Guadalaviar	8.900	40	10	..	..	..	54	1161		39	20	1175	14	681	919 350
Jucar	8 100	39	15	..	..	1	15	1176		39	00	1180	4	51	68 850
Segura	8 200	38	10	..	..	1	20	1194		38	06	1195	1	3	4 050
Guadalquiver	20.000	37	40	2	02	..	..	1202		36	42	1218	16	2 000	2 700 000
Guadiana	25.700	38	25	2	00	..	..	1190		36	48	1216	26	6,785	9.159 750
Caldoa	7.100	37	48	..	20	..	..	1200		37	40	1202	2	11	14 850
Tagus	28.900	40	00	3	50	..	..	1164		38	50	1183	19	4 075	5,501 250
Duero	38 700	41	30	3	05	..	..	1139		41	15	1142	3	135	182 250
Minho	10 600	42	41	1	15	..	..	1117		42	28	1121	4	66	89 100
Rivers of Great Britain	46 015	..	..	..	..	..	..	..		..	..	..	..	1,181	1 594 350
Rivers of Ireland	16,224	..	..	..	..	..	..	..		..	..	..	..	921	1,243 350
WESTERN HEMISPHERE.															
Bastard, Penticost	33 000	50	50	..	..	..	05	959		49	08	994	35	15.790	21 316 500
Saguenay	27 800	49	02	..	..	2	45	996		48	00	1017	21	4,788	6 463 800
St. John, Penobscot	34 400	46	40	..	..	1	00	1042		45	20	1068	26	9,081	12 259 350
Kennebec, Androscoggin, Saco	13,000	44	45	..	..	..	20	1078		43	55	1094	16	1.300	1.755 000
Merrimack	7 100	43	20	..	..	..	38	1105		42	48	1114	9	225	303 750
Connecticut	10 800	43	20	..	02	..	..	1105		41	10	1143	38	6,091	8.222 850
Hudson, Housatonic	16 000	42	30	..	04	..	..	1120		40	42	1152	32	6 400	8 640 000
Delaware	11 500	41	00	..	03	..	..	1146		39	35	1172	26	3,036	4 098 600
Susquehanna	27 200	41	14	..	..	..	52	1142		39	32	1172	30	9 561	12.907.350
Potomac, Rappahannock	16 000	39	00	..	..	1	15	1180		38	02	1197	17	1,806	2 438 100
James	13 100	37	32	..	..	1	32	1204		36	52	1215	11	619	835 650
Roanoke, Tar	18 800	36	36	..	..	1	40	1220		35	52	1231	11	888	1,198 800
Santee, Neuse	44 100	34	40	..	..	1	25	1249		33	42	1264	15	3,881	5,239 350

Savannah and others	51 200	32	51	..	..	1	05	1276	31	52	1290	14	3.917	5,287,950
Alabama district	128 700	31	30	..	25	..	..	1295	30	15	1312	17	14 543	19 633 050
Mississippi	1,244.000	40	55	..	..	7	10	1148	29	08	1327	179	14,323 668	19,336 951 800
Colorado, Brazos, Trinidad	191.200	31	12	..	..	1	50	1300	28	40	1333	33	81 354	109 827.900
Rio del Norte	215 500	29	50	..	..	6	40	1318	25	30	1371	53	236 457	319,216,950
Colorado	267.000	36	04	1	06	..	..	1228	32	15	1285	57	338 890	457,501,500
Rivers east coast of Gulf of California	140 000	28	06	1	10	..	..	1340	27	00	1353	13	9 240	12.474 000
Kalamath and Tsashtl	42 900	42	00	1	15	..	..	1129	41	45	1133	4	268	361 800
Columbia	283.400	45	52	7	02	..	..	1058	45	48	1059	1	111	149 850
Frazer	138 300	51	28	..	..	..	40	946	49	02	996	50	135 050	182 317,500
Simpson and Frances district	53 600	56	40	2	00	..	..	835	55	10	871	36	27 135	36.632 250
Atna or Copper	34 900	62	12	..	05	..	..	708	60	20	752	44	26 393	35 630 550
Bolsas, Yopez, Verde	71 500	18	00	..	05	..	..	1445	16	42	1455	10	2.788	3.763 800
Sirano district	24 700	14	00	..	10	..	..	1474	13	30	1477	3	86	116 100
San Juan de Nicaragua	23 700	12	00	..	..	1	20	1486	11	15	1490	4	148	199 800
Sacramento	33 000	40	00	..	..		08	1164	37	50	1200	36	16,706	22,553.100
Parahyba and Grande	37.600	6	40	..	..	1	50	1509	5	40	1512	3	132	178 200
Ciara, Croayhu	33 700	5	08	..	..	..	05	1513	3	10	1517	4	211	284 850
Jaguaribe	19.900	5	50	..	..	..	30	1511	4	30	1514	3	70	94.500
Belmonte and Doce District	114 400	17	25	..	..	1	48	1449	17	00	1453	4	715	965 250
Parahyba (South)	35 800	22	00	..	..	2	12	1408	21	30	1413	5	349	417.150
St. Francisco	247 600	14	00	..	..	7	00	1475	10	20	1494	19	34 912	47.131,200
Paranahyba	157 300	8	05	..	..	2	30	1504	2	58	1517	13	10 382	14 015.700
Maranhao and Itaqieura	59 600	5	00	..	..	..	40	1513	2	50	1517	4	373	503.520
Gurupy and Turyassu	49 000	3	20	..	..	1	00	1516	1	00	1519	3	172	232,200
Tocantins	376 000	10	10	..	..	1	00	1495	2	00	1518	23	77 738	104 946.200
Amazon	2,236,000	6	20	..	..	12	50	1510	1	25	1519	9	70 993	95,840,550

BALANCED SLIDE VALVES.—At the meeting of the Institute of Mechanical Engineers held at Birmingham yesterday week, a paper was read entitled "Description of a Balanced Slide Valve for Locomotive Engines," by Mr. William G. Beattie, of London. This slide valve is similar in shape to the old D valve, being made cylindrical at the back, and working inside a jacket of corresponding form fixed in the steam-chest; the steam pressure is exclued from the back of the valve by two steam-tight packing rings, one at each end of the valve, which are fitted into grooves in the body of the valve, and are pressed outwards against the jacket by means of spiral springs. The valve is thus relieved of the heavy pressure of steam, which in ordinary unbalanced slide valves forces the valve against the cylinder face with a pressure that amounts in large engines to as much as 9 or 10 tons on each valve. The result has been found by experiment to be that the balanced slide valves, which are made of cast iron, require only about one-third of the power to move them that is necessary with the ordinary unbalanced valves made of brass; the excessive wear and tear to which the ordinary valves and the link motion working them are subjected, is thus avoided with the balanced valves, and there is considerable saving both in first cost and maintenance; there is also an important advantage in the facility with which the engine can be reversed with steam on. The economy of fuel consequent upon the saving in the power required to work the balanced valves has been found by the experience of continued working to amount to 2½ lbs. of coal per mile run; and a large number of engines, both passenger and goods, have been fitted with these valves.

THE MECHANICS OF FLYING.

By LUDWIG KARGL.

Translated from "Der Civil Ingenieur."

The object of this investigation is to determine under what circumstances it is possible for a machine to raise itself in the atmosphere, and at the same time guide its motion in any given direction.

We learn from history that in ancient times attempts were made to imitate the flight of birds, and that the experiments all failed from defect of construction or lack of muscular strength. In modern times elevation into the atmosphere became possible by means of the balloon; but the problem of controlling direction remains unsolved. Sails and rudders do not work, because the aerial ship is entirely surrounded by air; and progression by sail, screw, rudder, or any other mechanism is not to be attained, because the balloon has so great a magnitude in proportion to its force of inertia, that the motors which it can carry with it are not sufficient to oppose the resistance of a strong counter breeze.

Of late, attempts have been made, especially in England, to follow the path pointed out by nature; that is, that of raising a machine without the aid of a balloon by means of wings driven by steam.

That no result has been so far obtained is explained by the fact that the mechanical work required for flying is very great; so that the weight of a very light flying machine is much too great compared with the work performed by it.

It is therefore surprising that Prechtl in his work, "Untersuchungen uber den Flug der Vögel; Wien, 1846," states that the mechanical work done by birds during flight is quite small, and that their muscular power does not greatly exceed that of other animals. The error underlying this statement will be shown in the course of this article. As the assumptions leading to this result were found to be unwarranted, the writer was compelled to proceed from entirely different data.

The object of this paper is at present confined to the determination, upon the basis of an investigation of the motions of flight, of the work per second necessary to maintain a flying-machine of given weight in the atmosphere, by means of wing-strokes. We shall thus find the weight per horse power that must not be increased, if the machine is to float in the atmosphere.

My thanks are due to Dr. Gustav Zeuner for his aid and share in this labor.

1.—RESISTANCE OF SURFACES IN MOTION IN AIR AT REST.

We first give the necessary theory concerning the resistance of the wing-surfaces.

Known deductions and experiments show that for plane or slightly curved surfaces the resistance (W) is proportional to the projection of the surface, normal to the direction of motion (F), and also to the square of the velocity (v), as well as to a constant c, determined by experiment, giving

$$W = c.\frac{F\,v^2\,\gamma}{2\,g};$$

γ being the density of the atmosphere; that is, the weight of a cubic metre of air at standard thermometer and barometer, and g being the acceleration due to gravity = 9.81 metres.

In considering the motions of wings, we have to do, not with rectilinear but with angular motion.

The resistance of a surface element at the distance x from the axis of rotation is

$$d\,W = k\,a^2\,x^2\,y\,dx,$$

k being $= c\,.\,\frac{\gamma}{2\,g}$, and a being the angular velocity.

The total resistance of the surface is

$$W = k\,a^2 \int y\,x^2\,dx = k\,F\,a^2\,\frac{\int y\,x^2\,dx}{\int y\,dx} = k\,F\,a^2\,n^2$$

The resistance of the rotating surface is therefore equal to the resistance of the same surface moving in a straight line with the velocity of a point at the distance n from the axis. This point will be called the point of resistance. This lies at the distance

$$n = \sqrt{\frac{\int y\,x^2\,dx}{\int y\,dx}}$$

Special Cases.—1. Let the surface be a rectangle $a \times b$, revolving about the side b; then

$$n_r = \frac{a}{\sqrt{3}} = 0,577\, a.$$

2. Let the surface be a parabola. This may be taken as an approximation to the wing form. The equation is

$$y^2 = p\, x^1.$$

As Y is the axis of rotation

$$y^2 = p\,(l-x).$$

For

$$y = g,\ x = 0,$$

and

$$y^2 = \frac{g^2}{l}\,(l-x),$$

giving

$$n_p = l\,\sqrt{\frac{8}{35}} = 0,479\, l.$$

2.—MOMENT AND POINT OF APPLICATION OF THE RESISTANCE.

The moment of the restance is

$$W_m = a^2\, k \int y\, x^3\, dx$$

and the distance of the point of application from the rotation-axis is

$$m = \frac{\int y\, x^3\, dx}{\int y\, x^2\, dx}$$

Special Cases.—1. For the rectangle $a \times b$, about the side b,

$$m_r = \frac{3}{4}\, a.$$

2. For the parabola with axis perpendicular to the rotation-axis, and distant l from it,

$$m_p = \frac{2}{3}\, l.$$

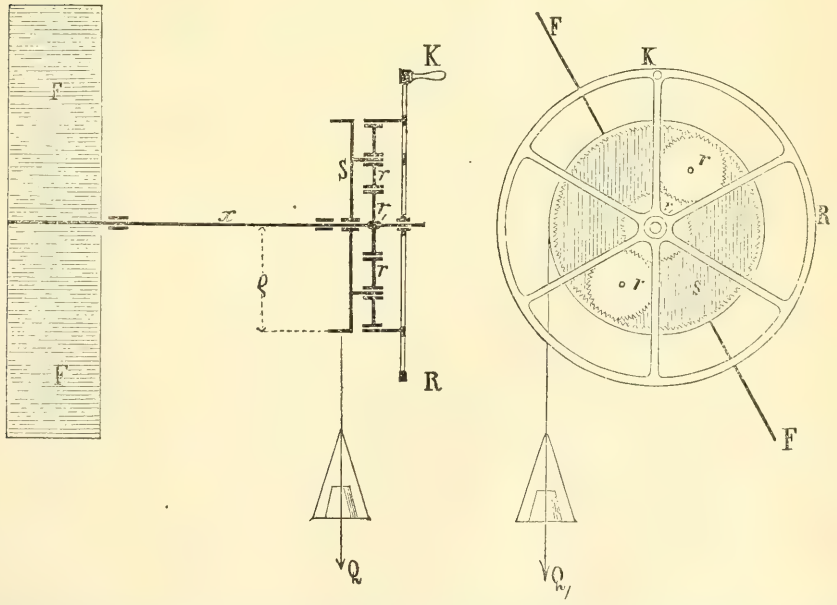
In Prechtl's work this distinction between the point of resistance and the point of application of the resistance is not made. Still, this error has no important influence upon the final result.

3.—EXPERIMENTS TO DETERMINE THE COEFFICIENTS OF RESISTANCE.

If a surface revolves in air at rest, the parts at a greater distance from the axis have a greater velocity than those nearer, hence the rarefaction increases outward from the axis, and, as a consequence, there is a flow of air radially outwards. Hence a greater quantity of air is set in motion than in the case of rectilinear motion, and the coefficient c must therefore be larger.

In my experiments I employed the dynamometer represented in Fig. 1. Upon its axis χ a double wing F was fastened,

FIG. 1.



so that resistance of the air formed a couple that did not increase the pressure upon the axis. The disk S, of radius ρ, runs loose on the axis, and carries driving

teeth for the intermediate wheel r. These act upon the wheel r_1, which is locked to the axis, being moved by the large wheel R. If the crank K is turned just so fast that the scale containing the weight Q_1 remains stationary, then the resistance at the surface of the disc S is equal to Q_1. Therefore if the wheels r are equal to the driver r_1, the resistance of the atmosphere upon the whole surface *plus* the resistance due to friction must be

$$W_1 = \frac{Q_1 \rho}{3m};$$

The pair of wings consisted of a light wooden frame 1.5 m. long by 0.3 m. broad, covered with cartoon paper. In order to eliminate the friction and resistance of the wooden frame the paper was removed and the frame revolved. This resistance is

$$W_2 = \frac{Q_2 \rho}{3m};$$

hence the resistance of the air

$$W = W_1 - W_2 = \frac{\rho}{3m}(Q_1 - Q_2)$$

The radius of the disk S is $\rho = 0{,}1675$ met. ; barometer at 720 millim ; temperature 20° Cels. ; hence, the density $\gamma = 1{,}141$ kilog.

Let u = number of revolutions per minute ; the results are then as follows :

Q_1 =	2	2 5	3	3.5	4	4.5	5	5.5 kil.		
u =	21	23.5	26	28	30	32	34	36		
Q_1 =	6	6.5	7	7.5	8	8.5	9	9.5	10	
u =	37.5	39	40	41	42	43	44	45	46	
Q_2 =	0.5	1	1.5	2						
u =	20	31	41.5	51						

Constructing a curve having for abscissas the number of revolutions per minute, and for ordinates the corresponding values of Q_1 Q_2, it is obvious from its form that the resistance of the atmosphere increases somewhat more rapidly than the square of the velocity. We find for

u ..... =	20	25	30	35	40	45
v the velocity in terms of radius of resistance ..) =	0.91	1.13	1.36	1.58	1.82	2.04
C ..... =	6.3	6.1	6.3	6.5	6.5	7.3

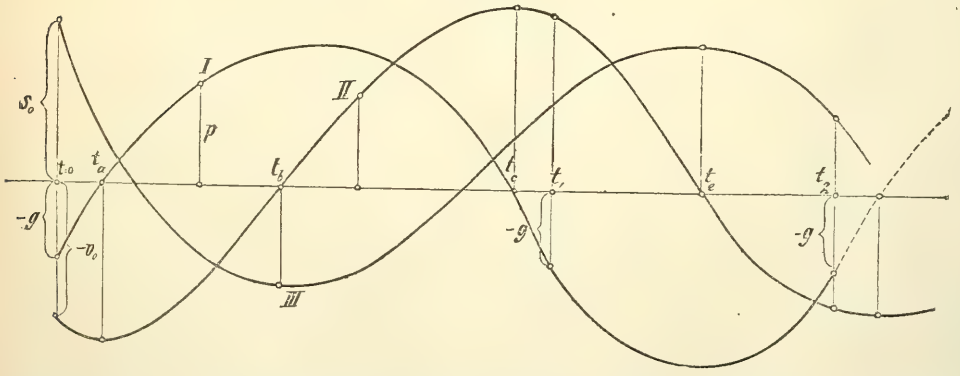
These values may seem somewhat large, but the experiments, though not exact, are sufficiently so for the end in view, and the deduced number of wing-strokes of birds corresponding to these coefficients agrees closely with the results of observation.

4.—INVESTIGATION OF THE MOTIONS OF FLYING.

When the law of motion of wings is known, and the wing-surface is given, the resistance W at any time can be determined.

The vertical component of this resistance (the buoyant effort) and the total weight G act at the centre of gravity. If upward direction is positive, then during the down-stroke the buoyant effort *minus* the weight acts in the direction of motion, *i. e.*, K = A − G. During the back-stroke the buoyancy is negative; hence the last equation represents the force acting at the centre of gravity if the proper sign is given to A. Hence the centre of gravity moves with an acceleration $p = \frac{K\,g}{G}$.

FIG. 2.



Setting off the time as abscissa, and the acceleration as ordinate, we obtain a curve (I) Fig. 2, which can be determined when the law of flight is known. The surface bounded by this curve, taken between 2 ordinates, gives

$$\int p\,dt = v_1 - v_0;$$

that is the increase of velocity of the the centre of gravity during the time represented by the intercept between the ordinates.

If the initial velocity (when $t = o$) is given, the velocity at any time can be found. This gives a second curve (II). The surface limited by this curve, taken between 2 ordinates, is

$$\int v\,dt = s_1 - s_2,$$

and hence it represents the increase of the path of the centre of gravity during the time represented by the intercept between the ordinates.

If the initial space (for $t = o$) is given, the position of the centre of gravity at any moment can be found; giving the curve III.

If the wing begins a down-stroke at $t = o$, then $p = g$. The acceleration for $t = t_a$ is o; hence the negative velocity is a maximum at this point. At t_3 the velocity is o; hence at this point the positive velocity is a maximum. At $t = t_1$ the down-stroke ends and the return-stroke begins. At t_e the velocity is o; hence the stroke is a maximum. At t_2 the back-stroke ends, and the period begins again. These 3 curves, therefore, completely represent the circumstances of motion of the centre of gravity, giving the position and velocity at any moment.

The motion of the wings should be so adjusted that the velocity at the end of each down-stroke shall be zero; otherwise a certain amount of work would remain stored up in the wing, thus remaining ineffective.

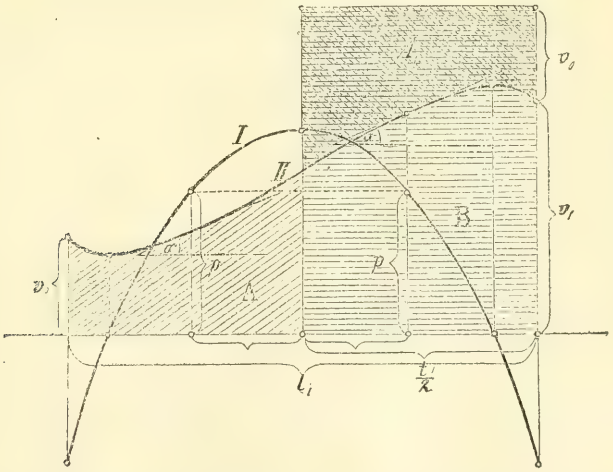
Prechtl assumes that the motion of the wing is uniformly accelerated, so that the final velocity is also the maximum velocity, which, according to the above analysis, would not be an economical disposition.

Without assuming a fixed law of motion I will suppose that the motion of the wings is symmetrical in relation to their (horizontal) middle position. Then the buoyant action and the force K acting at the centre of gravity is equal in magnitude and direction for two positions of the wings at equal distances above and below their mean position. And the time required to pass from a given position to the mean place is equal to the time required to pass from the mean position to a position at equal distance below.

It follows that the curve I, which represents the relation between time and acceleration, is symmetrical with reference to the mean position.

Concerning the course of the curve II, which gives the relation between velocity and time, we find that the angle of the tangent with the axis of abscissas at a point on this curve is $p = \frac{dv}{dt}$; hence it is equal for two positions, equally distant above and below the mean plane (Fig. 3.)

FIG. 3.



It follows that the obliquely hatched surface A must be equal to the obliquely hatched surface A_1. The entire surface bounded by the curve II and the axis of

abscissas represents the space described by the centre of gravity during the back-stroke (in the time t_1.) This surface then is equal to the rectangle B, and

$$s_1 = \frac{t_1}{2} (v_1 + v_0)$$

This formula derived for equally accelerated motion, also holds for any kind of motion, provided that the accelerating force after a certain time decreases according to the same law by which it has increased; and the law holds for points equally distant from the mean position.

During the back-stroke, the space described by the centre of gravity is

$$s_2 = \frac{t_2}{2} (v_1 - v_2)$$

and the path for an entire period is

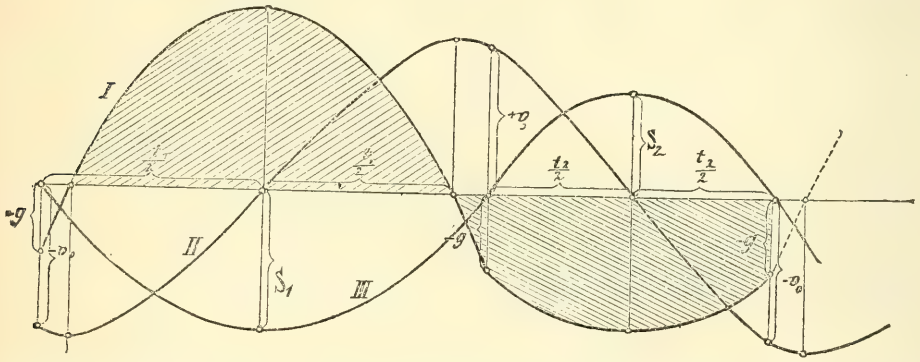
$$S = s_1 + s_2 = \frac{t_1}{2} (v_1 + v_0) + \frac{t_2}{2} (v_1 + v_2).$$

Therefore, in order that there may be rising on the wings, the velocity of the centre of gravity at the end of the down-stroke must be equal, and opposed in direction to the velocity at the end of the back-stroke.

Again, the centre of gravity at the ends of both strokes must lie in the original positions (Fig. 4.)

At the time $t = o$ (beginning of the down-stroke) the velocity is $-v$. At the moment when the buoyant force is equal to the weight of the apparatus, this velocity is a negative maximum. From this point it diminishes, until it becomes 0, when $t = t^1$ (mean position, wings horizontal). At this time the space is a negative maximum $= S_1$. The velocity is now positive, the negative path is less, until $t = t^1$, when the velocity $= +v$ and the space $= 0$. The back-stroke

Fig. 4.



now begins. The centre of gravity is at the initial position, but has a positive velocity v, and consequently the path is positive. The velocity diminishes, until at the middle position it becomes 0, and the space in the positive direction is a maximum $= S_2$. Now the velocity is negative, the space diminishes, and at the end of the back-stroke (after a complete period) the initial circumstances recur. The centre of gravity is at the initial position and has the velocity v. These results hold for any motion which is symmetrical with reference to the mean position.

As the surface included between the curve II and the axis of abscissas is equal to the increment of the path of the centre of gravity in the interval of time represented by the distance between the ordinates, and as this increment for an entire period is equal to zero, this surface for the interval t_1 to t_2 must be taken equal to zero; consequently the portion above the axis of abscissas must be equal to the portion below.

And as the surface included between the curve I and the two ordinates is equal to the increase of the velocity of the centre of gravity in the interval represented, and as this increase for an entire period is zero, this surface for the interval from t_1 to t_2 must be taken equal to zero, and the hatched portion above the axis of abscissas must be equal to the hatched portion below.

This gives a very convenient means of determining directly the equation of condition for rising. It may be expressed as follows:

Set off the times as abscissal; the accelerating force (buoyancy *minus* weight),

acting at the centre of gravity, as ordinates; then for an entire period the corresponding surface must be divided into two equal parts by the axis of abscissas.

5.—OF THE LAWS OF MOTION OF THE WING SURFACES.

For the construction of an artificial flying apparatus, motion by means of crank motion is recommended, because this is the simplest mechanism corresponding to the condition, that the velocity at the end of each stroke shall be zero. The law of crank motion does not give exactly the motion of the wing surfaces relative to air at rest: first, because the centre of gravity is in motion; and again, because, in consequence of the motion of the wings, which have a certain weight, the main body of the apparatus has a motion relative to the common centre of gravity. This motion is analogous to the oscillating motion of locomotives, and is due to the laws of the motion of the centre of gravity. But these motions have no important influence upon the buoyancy generated by the wing surfaces, because —

(1.) As regards the velocity of the centre of gravity of the entire apparatus, it is always small compared with the velocity of the wings. This influence is still less, because it is greatest near the beginning and end of the strokes, and therefore at points where (except for large stroke-angles) the wing surfaces have first departed a little from the vertical position; hence the vertical velocity of the centre of gravity cannot have much influence upon the resistance of the wings. If the wing is horizontal (at mean position), the velocity is zero in any event, and for small angles it generally disappears entirely.

(2.) As regards the motions of the wing frame, these are so slight that the ratio of the weight of wings to that of the body is insignificant.

[TO BE CONTINUED.]

BRONZE FIELD GUNS.

From "Engineering."

When argument and common-sense reasoning fail to convince of error, practical results generally step in and right matters, except, perhaps, where obtuseness is only rendered more obtuse by the absoluteness of the failure. There are some people who will never change their ideas, although their pet schemes lie exploded before their very eyes. Whether Col. Maxwell will accept as a decided defeat the recent failure of the bronze guns at Shoeburyness we know not. For the sake of the army, however, and of the nation dependent upon it, if not for his own sake, we recommend him to do so. The results of the recent trials have been kept as quiet as possible; but notwithstanding this, it is now well known that the three bronze 9-pounder guns taken for testing as samples from the batch recently cast at Woolwich, have proved signal failures. This is not to be wondered at when we reflect that they are the embodiment of Col. Maxwell's opinions upon the subject, and of which he is so proud as being the reflex of opinions held four and a half centuries since. Fortified by such a fortuitous circumstance as this must be, we may presume that Col. Maxwell will still adhere to this opinion, its very antiquity being in his eyes sufficient proof of its correctness. The three guns in question were made at the Royal Gun Factory, Woolwich, and we may be quite certain that nothing was left undone that could be done in order to render them a success, except only that one element was omitted—common sense. These guns all failed after about 200 rounds had been fired from each of them, large holes and deep fissures being developed in the bores. To what cause this may be owing we do not now stay to inquire, not having examined the guns. Probably the metal, which is that of some of our old bronze guns, suffered in remelting, the tin, which has to be added at each remelting, not properly amalgamating with the body of the metal, but collecting in small pockets. These would form soft spots on which the action of firing would soon tell. That this is the case indeed seems clear, for it is not ordinary erosion that has occurred,

and this probability is strengthened by the wide difference between the melting temperatures of copper and tin.

Guns of this metal, when made sufficiently hard to withstand friction and erosion, are too brittle to resist the shock of the explosion of the charge. On the other hand, if the metal be of a sufficient degree of toughness, so as not to break, it will be too soft to withstand the action of the powder when fired. When smooth bores and round shot were the fashion, the percentage of defective castings in bronze guns was very high, whilst with rifled ordnance that percentage has greatly increased. With new metal these results are bad, but when old guns are remelted it is infinitely worse, for the reasons we have given. So difficult is this metal to manage, and so thoroughly unreliable is it in itself, that of two guns cast from the same run of metal, one may turn out well whilst the other will be a positive waster. The difficulties which attend the successful manufacture of bronze guns were well understood at Woolwich, and attempts were made to overcome them, with what success let the three miserable examples at Shoeburyness tell. The first and experimental guns proved more successful, but those sampled from a working batch have told a different tale. The truth is that the appearance of these fissures, from what cause soever they may proceed, only anticipates the failure which would inevitably have resulted soon after twice 200 rounds had been fired from each of them. The French bronze guns are usually recast after about 500 rounds, and we see no reason why English guns made of a similar compound should stand any better. There is no doubt that a trial of one of these guns, if pushed a little beyond the above figures, would develop what Col. Maxwell terms "ample indication of approaching rupture;" that is, the gun would burst and a good-sized piece would be "thrown out of the chase with violence." This we are inclined to consider a decided rupture of itself, and not a mere indication of that event as Col. Maxwell does. It is fortunate for the interests of the public that these results have followed, as well as for the progress of the science of gunnery, which, however, could not have been much retarded by the perpetration of such a blunder. But the bane and the antidote lie very close together, and we commend this failure to the special notice of all those who have not sufficient intelligence to enable them to discriminate between the relative merits of bronze and steel for field guns.

International Pacific Railway.—An International Pacific Railway Company proposes to apply to the Parliament of the Dominion of Canada in its next session for an Act of Incorporation. The proposed line would branch from the Grand Trunk of Canada, and run to Sault Ste. Marie, where it would cross the river, and pass through American territory, coming into Canadian soil again at Pembina. From Pembina it would run *via* Fort Garry to the Pacific.

Brazilian Enterprise.—A concession has been granted to some Brazilian gentlemen for working the Taubate coal beds in Sao Paulo. The President of Maranhao is promoting the formation of a company with a capital of £40,000, to take up and deepen the abandoned canal of Araparahy, which will connect two important river navigations. His Excellency proposes to assist the undertaking with a provincial guarantee of interest.

New Zealand Railways.—Surveys for lines in the province of Auckland, New Zealand, have been rapidly proceeded with of late. In going over old surveys, it has been found necessary to lay down a new line in most places, as in consequence of luxuriance of undergrowth and the rapid decay of timber used as marks, all vestiges of a line laid out some time since had become obliterated.

Richelieu, Drummond, and Arthabaska Railway.—The Company which is carrying on this Canadian line, has ordered 2 locomotives and 50 platform cars to be delivered on the line of the road by May 1. The locomotives are to be of the same make as one in use on the Quebec and Gosport Railway. The new line will run from Sorel to Acton, on the Grand Trunk Railway of Canada.

THE STEAM INJECTOR.

By A. WINKLER.

Translated from "Zeitschrift des Vereines Deutscher Ingenieure."

According to the mechanical theory of heat, mechanical work and heat are equivalent. To each unit of heat corresponds a work of 424 metre kilograms, the heat-unit being the amount required to raise a kilogram of water 1° Centigrade. To produce a work of one horse-power or 75 metre-kilograms, $\frac{75}{424}$ heat-units per second are necessary, or 636.8 heat-units per hour; whatever the nature of the working body and whatever the law of cooling.

Steam is generally employed in the conversion of heat; the process being briefly as follows: steam is generated under constant pressure, it is then allowed to expand in the cylinder without further application of heat, then to pass off freely, or into the condenser, from which it passes again as water into the boiler.

To produce a kilogram of a mixture of water and steam under constant pressure, if the feed-water has a temperature of 0° the following conditions are necessary:

(1). The water must be raised from the zero point to the temperature, t_1 of the steam, for which a quantity of heat $q_1 = \int_0^{t_1} c\,dt$ is required, c being the specific heat under constant pressure.

(2.) If each kilogram of the mixture contains m_1 kilograms of steam and $1 - m_1$ kilograms of water, then an internal latent heat $m_1 \rho_1$ is required to generate m_1 kilograms of steam.

(3.) The constancy of pressure requires a continuous discharge of steam, corresponding to the work $p_1 m_1 (v_1 - \sigma)$, or to a quantity of heat $A\ p_1\ m_1\ (v_1 - \sigma)$; in which $A = \frac{1}{424}$, the equivalent of heat for a unit of work; p_1 = the absolute steam-tension (expressed in kilograms) to the square metre; V_1 = the volume of 1 kilog. of steam; σ = the volume of 1 kilog. of water; hence $m_1 (v_1 - \sigma)$ = the increase of volume of 1 kilog. of mixture.

(4.) Continuous supply is also necessary, corresponding to a work $= p_1 \sigma$, or to an amount of heat $= A p_1 \sigma$.

Hence the amount of heat needed to generate a kilogram of mixture is

$$Q_1 = q_1 + m_1 \rho_1 + m_1 A p_1 (v_1 - \sigma) + A p_1 \sigma \quad (1.)$$

Employing the sub-index 2 for the corresponding quantities at the final condition of the steam, we find the quantity of heat that must be withdrawn from the expanded steam to convert it into water of the temperature 0° is

$$Q_2 = q_2 + m_2 \rho_2 + m_2 A p_2 (v_2 - \sigma) + A p_2 \sigma \quad (2)$$

The quantities in equations (1) and (2) can be taken from tables, with the exception of m_1 and m_2. If m_1 is determined, m_2 is found by means of the equation of the adiabatic curve, *i. e.*, the curve of variation without reception or emission of heat:

$$\frac{m_2 r_2}{T_2} + r_2 = \frac{m_1 r_1}{T_1} + r_1 \quad (3.)$$

in which

$$r = \int_0^t \frac{c\,dt}{T} \text{ and } r = \rho + A p (v - \sigma)$$

and T, the absolute temperature $= (273° + t°)$ C.

As the work in the cylinder was without reception or emission of heat, the quantity of heat converted into work is simply expressed as follows,

$$A L = Q_1 - Q_2 = q_1 - q_2 + m_1 r_1 - m_2 r_2 + A \sigma (p_1 - p_2) \quad (4.)$$

Consequently the ratio of consumed to received quantity of heat is

$$\eta = \frac{Q_1 - Q_2}{Q_1} = 1 - \frac{Q_2}{Q_1} = \frac{A L}{Y_1} \quad (5.)$$

The consumption of steam expressed in horse-power for an hour, is found from the equation $G \cdot A L = 636.8$; from which

$$G = \frac{636.8}{A L} = \frac{636.8}{Q_1 - Q_2} \quad (6.)$$

And the fuel consumption per horse-power for an hour is

$$W = G.Q_1 = \frac{636.8}{\eta} \text{ units of heat.} \quad (7.)$$

The following table is calculated from these formulæ:

p_1	p_2	m_1	m_2	Q_1	Q_2	A L	η	G	W
5 atmospheres	1 atmosphere	1.00	0.909	653.049	588 202	64 847	0.0993	9.82	6412.6
		0.80	0 746	553.212	509.592	52 620	0 0951	12 10	6696.1
	0.5 "	1.00	0 877	653.049	563.856	89.193	0.1366	7 14	4661.8
		0.80	0.725	553.212	480.347	72.865	0 1317	8.74	4835 2
10 atmospheres	1 atmosphere	1.00	0.873	661.738	568.888	92.850	0.1403	6.86	4538.8
		0.80	0 726	565 983	490.023	75 960	0.1342	8 39	4745.2
	0.5 "	1 00	0.843	661 738	545 176	116 562	0.1761	5 46	3616.1
		0.80	0.707	565.983	470.458	95.525	0.1688	6 67	3772.5

The values of G and W are much smaller than those generally taken in practice, because of the neglect of hurtful resistances of all kinds. The values of η show that the steam engine is a very wasteful machine, since 0.85 @ 0.9 of the applied quantity of heat is lost. In the determination of the values of Q_1 conditions are assumed which are not fulfilled in practice; for example, a boiler is never fed with water at 0°; and in finding the work $p_1 \sigma$ of the feed pump, the absolute pressure p_1 is made use of, though this is greater than the suction-height. The quantity of heat employed in feeding is very small and without influence upon the value of η, but previous warming of the water may serve to economize considerably; for the quantity of heat q_0 contained in the water is to be taken from Q_1, while the difference $Q_1 - Q_2$ remains the same; the heat Q_2 in the emitted steam is also diminished just as much, provided that the warming of the water is effected by means of the emitted steam or by previous heating. To pass to the other extreme, suppose the feed water heated to 80°, corresponding to a quantity of heat q_2=80,282, we shall find the values of η as stated in the following table:

Water at 0	$\eta = 0.0993$	0.0951	0.1366	0.1317	0.1403	0.1342	0.1761	0.1688
" 80	$\eta = 0.1132$	0.1113	0.1557	0.1541	0.1596	0.1564	0.2005	0.1967

Notwithstanding the high temperature the value of η is still quite small, and in ordinary practice the only use of it is that $Q_1 - Q_2$ is made as large as possible; that is, great steam tensions are employed and worked with great expansion. Yet there is another application not yet realized in practice; this consists in pumping the steam into the boiler instead of condensing it. The cyclic process of the steam engine is by this means simplified in a great degree, and the only question remaining is, whether the work so gained leads to better or worse use of the admitted quantity of heat.

Of the many means employed to restore the steam from the cylinder, without condensation, to its original condition, the simplest and most available is the injector.

Let G, as before, indicate the quantity of steam consumed in an hour per horse-power, which must be returned to the boiler; G_0= the quantity of steam required by the injector in the same time; we then have the amount of heat contained in G_0 (if the water held in G_0 and in G is the same):

$$G_0 Q_1 = G_0 (q_1 + m_1 r_1 + A p_1 \sigma)$$

and the quantity of heat contained in the steam taken up is

$$G Q_2 = G (q_2 + m_2 r_2 + A p_2 \sigma).$$

After the admission of $G_0 + G$ kilog. of mixture into the boiler the quantity of heat contained is

$$(G_0 + G) Q_0 = (G_0 + G) q_1 + m_3 r_1 + A p_1 \sigma)$$

and as heat has neither been added nor withdrawn during the proeess, the quantities before and after mixture must be equal, *i. e.*:

$$(G_0 + G)(q_1 + m_3 r_1 + A p_1 \sigma) = G_0 (q_1 + m_1 r_1 + A p_1 \sigma) + G(q_2 + m_2 r_2 + A p_2 \sigma).$$

This formula leads to the equation for the water injector given by Prof. Zeuner, if m_3 and $m_2 = 0$, and for $p_1 \sigma$ the suction height h is substituted; and also, instead of q_1, the quantity of heat q^1, due to the introduction of the mixture into the boiler, from equation (8)

$$G_0 = G \left(\frac{A L}{r_1 (m_1 - m_3)} - 1 \right)$$

$$G_0 = 636.8 \left(\frac{1}{r_1 (m_1 - m_3)} - \frac{1}{A L} \right) \qquad (9.)$$

in which G_0 is expressed in kilograms for horse-power per hour.

There are consequently $G_0 + G$ kilog. of water and steam at boiler temperature, but containing less steam; to bring this mixture to the original working condition the quantity of water $(G_0 + G)(m_1 - m_3)$ must be converted into steam, requiring a quantity of heat

$$W = (G_0 + G)(m_1 - m_3) r = G.AL \qquad (10.)$$

and this is the same quantity of heat which is converted into work by the machine; hence, in consequence of this process, the steam engine would be not only a very economical but a perfect and exact motor, since η reaches its highest value, *i. e.*, 1; no reference being had to hurtful resistances.

Equation (9) leads to the following conclusions:

(1.) The value m_3 must always be less than m_1; hence, during the whole process there is neither formation of steam nor superheating.

(2.) The value of r_1 makes the quantity of steam G_0 depend upon the steam-pressure in the boiler; and the amount of steam required seems to increase slowly with increasing pressure.

(3.) The steam required in suction has a peculiar relation to the condition of the steam used, in consequence of the value A L. If A L, that is, the work of each kilogram of steam is large, and therefore of high expansive power, with great difference in initial and final conditions, then G_0 must be large, or larger than in case of weak expansion and high final value. In machines of variable expansion, therefore, the quantity of steam G_0 in the injector should be subject to regulation; if the apparatus, in consequence of the indetermination of m_3, is not automatic; for the formula (9) indicates only the limits of m_3 that should not be passed; and of these limits

$$\left(m_3 = m_1 \text{ and } m_3 = m_1 - \frac{AL}{r_1}\right)$$

the first gives $G_0 = \infty$; the other, $G_0 = 0$. In general, to every value of G_0 or m_3 corresponds a determinate curve of variation, and the object is to determine those values which reduce the dimensions of the apparatus to a minimum, and at the same time afford the greatest scope of application.

To reduce the dimensions to a minimum, it is better not to pass with m_3 beyond m_2; as a part of the heat contained in G_0 would be expended in the generation of steam, which is not the object of the apparatus. To obtain a better suction the value of m_3 should be a little less than that of m_2; in consequence of which the steam G is a little more condensed, and the heat set free, or the work can aid the action of the injector. The limits of m_3 are

$$(\text{max.})\ m_3 = m_2\ ;$$
$$(\text{min.})\ m_3 = m_1 - \frac{AL}{r_1} \qquad (11)$$

As m_1 and m_2 in practice are not exactly fixed, there is always an uncertainty in the determination of the value G_0, which can be obviated only by practice.

(4.) In formula (9) m_1 may be greater or less than unity; that is, the steam may be saturated or superheated. In the latter case it is conceivable that the superheating may be carried so far that the whole amount of heat G.A L is communicated to the steam entering the injector, and the boiler would need no more heating. For it, might be substituted a simple steam reservoir, with or without water space depending on the value of m_3, whether greater or less than unity. In the latter case the steam-engine would be converted into a permanent gas-engine. Either case represents a simpler and cheaper project than the ordinary engine. It is to be wished that those conjectural improvements may somehow be realized in practice, so that 80 per cent. of the fuel used in heating the steam engine may not be lost to its effective work.

American Rails.—The first American rail was rolled some 30 years since. Last year more than 600,000 tons were made, more than half in Pennsylvania, the rest in New York, Troy, Rome, Syracuse, Elmira, and Buffalo.

Brazilian Rivers.—Surveys of the rivers Macao and Mossoro, in the province of Rio Grande del Norte, are about to be made with the view of forming plans and estimates for improving the navigation and marking off their respective channels.

The Sutro Tunnel is in 1,800 ft., and has struck a large body of water.

STEEL TYRES.

From "Engineering."

The recent disastrous accident at Hatfield, on the Great Northern Railway, resulting from the breakage of a steel tyre, and the fact that a number of such tyres have broken on different lines during the inclement weather of the last fortnight or so, although fortunately without giving rise to fatal results, renders it desirable that the attention of railway managers should be directed to a point of danger connected with the use of such tyres, which does not always receive the consideration it deserves. The point to which we refer is the excessive hardness too frequently given to the steel of which tyres are made. The first steel tyres largely used in this country were those manufactured by Krupp, and they were tyres made of a far softer kind of steel than is commonly used for such purposes. Experience, in fact, showed that a harder kind of steel could be used with safety, and Krupp himself has considerably increased the hardness of his tyres since their first introduction. As the tyres of other makers came largely into the market there arose a strong competition, which has its effect not merely on the price on the tyres, but on the nature of the material of which they were made, the endeavors of the rival manufacturers to obtain a high "mileage" from their tyres leading them to employ, in many instances, steel of a far harder kind than is advisable on the score of safety.

Railway superintendents, are, we fear, frequently apt to attach somewhat too much importance to the power of a tyre to resist wear, and too little to the dynamic strength of the material of which it is made ; but we trust that the recent accidents may lead to an improvement in this respect. We have seen steel tyres bent cold, so that the opposite sides of the hoop met, and this without showing any sign whatever of fracture ; but we believe that but a small proportion of the tyres now made, and most highly commended for their wearing qualities, would stand anything like such a test satisfactorily. It should be endeavored to obtain durability for a tyre by closeness and uniformty of texture, and not by excessive hardness, and it is especially advisable that railway engineers should take more effectual means to ascertain the precise character of the material they employ than is now very generally the case.

Another point also to which it is desirable we should direct attention is the excessive amount of shrinkage, but too frequently given to steel tyres. The shrinkage which it is desirable should be given to a tyre ought to be determined by two things—namely, the elasticity of the material of which the tyre is composed, and the rigidity of the wheel upon which it is placed. The greater the elasticity of the tyre, and the less the rigidity of the wheel, the greater the amount of shrinkage which may be safely given. When a tyre is in use, a strain is put upon it by the action of centrifugal force, and in the case of a wheel running at express speed, or, say, about 50 miles per hour, this strain amounts to about 4 tons per square inch of section, it being supposed that the whole strain is resisted by the tyre itself, and not by the fastenings. In shrinking on a tyre, the initial strain put on should be slightly in excess of that produced by centrifugal force at the highest speed at which the wheel is to be run, so that the only effect of the centrifugal force may be to diminish the grip of the tyre on the wheel, but never to cause the tyre to become loose on the latter, or to put a radial strain on the fastenings so long as the tyre remains unfractured. The amount of excess of the initial tension above that due to centrifugal force, which it is desirable to give to a tyre, will depend upon the material of the latter and its tendency to become stretched in use. With steel tyres of moderate hardness, the amount of this excess need be very small.

We have said that the amount of shrinkage given to a tyre should depend upon its hardness and the rigidity of the wheel upon which it is placed ; and it is in estimating this latter quantity that the main difficulty in determining the proper shrinkage exists. A steel tyre of moderate hardness and average good quality will, if put upon a perfectly rigid wheel, have an initial strain of about $3\frac{1}{2}$ tons per sq. in. put upon it for each $\frac{1}{100}$ in. shrinkage allowed per foot of diameter. Thus an allow-

ance of $\frac{1}{500}$ in. per foot, or, say, $\frac{1}{16}$ in. in a tyre of 3 ft. internal diameter, would involve an initial tension of about 7 tons per square inch. But in practice there is no such thing as a perfectly rigid wheel, and even with strong wheels of the ordinary construction, the amount by which the wheel would be compressed by the application of the tyre, would probably be sufficient to reduce the strain just mentioned to 4 tons per square inch or less, an amount which is, perhaps, scarcely as great as is required. The above calculation of the strain produced by shrinkage is founded on the supposition that the steel of which the tyre is composed will stretch about $\frac{1}{12500}$th of its length for each ton per square inch of tensile strain within the limits of perfect elasticity. If the tyre is composed of harder material the initial strain put upon it by the shrinkage will, of course, be proportionally greater. The increase which has been made in the hardness of tyres has thus rendered excessive the amounts of shrinkage which were fixed upon when the tyres were made of a softer class of steel. Moreover, the use of steel tyres has led in many instances to the employment of stronger and more rigid wheels than formerly, and this again has been the cause of an increase in the initial tension due to a given amount of shrinkage. In America, where steel tyres were sometimes applied to cast-iron wheels of a very rigid kind, it has been found necessary to employ much smaller amounts of shrinkage than are usual in this country.

It is a very common thing to ascribe the breakages of tyres which occur in winter to extra tightness caused by the cold; but we consider that the influence of temperature in this way has been greatly overrated. It must be remembered that if the tyre shrinks, the wheel shrinks also, and it is only any excess of the latter shrinkage over the former which can give rise to increased strain. One very important action of the frost is to make the permanent way more rigid, and thus increase the shocks and jars to which the tyres are exposed, and it is in this way, more than any other, that we believe the cold weather increases the number of fractures.

THE POWER AND CAPABILITIES OF WAR ROCKETS.

From "The Engineer."

History abounds with cases of the following kind:—An invention dawns, under the auspices of some enthusiast, who, vaguely dreaming of powers and capabilities beyond his grasp, forces his invention into notice and adoption prematurely. The invention is tried, found deficient in some respects, is set aside, and the inventor summarily relegated to the ranks of dreamers, quacks, and charlatans, with which sensible people had better have nothing to do. Meantime some collateral aid is undergoing development—some new power is coming into existence, which, if it only had been known simultaneously with the now abandoned invention, would have made it, not perfect, indeed—for what thing on earth is perfect?—but sufficiently adapted to the end proposed. If we do not err, the history of war rockets in Europe affords a case in point; not that war rockets are abandoned, or near abandoned, but, viewed from Congreve's stand-point, they have fallen somewhat into disrepute. We say in Europe, for rockets had been used in China and Burmah as war projectiles long ages before Congreve turned his attention to the perfecting of this powerful but somewhat erratic arm. Congreve was an enthusiast, as every inventor ought to be. Many—we will even say *most*—of his hopes and aspirations in respect to the capabilities of war rockets have not been borne out. The proposition he was never weary of repeating, "That war rockets comprehend the power of artillery everywhere, with the weight of artillery nowhere," is so manifestly untrue that we would not for one moment endeavor to uphold it. Rockets have not, in the first place—and no reasonable man, keeping mechanical principles in view, will expect them to have—the accuracy of cannon, especially rifled cannon; but when this has been admitted little remains to be said against them. Rockets, notwithstanding their deficiencies, have taken their stand in many services. We use them with effect, so does Austria. In mountain war-

fare, such as we had in Abyssinia, their utility is incalculable, as they are easily conveyed over obstacles that to guns would be impassable. Against troops in the open, and more especially cavalry, rockets, when they do take effect, are beyond endurance horrible. At Leipsic the only English troops present were the Congreve rocketers; and though the rockets of that early date were imperfect things, with side-sticks, like ordinary pyrotechnic rockets, their effects were so terrible that the enemy against whom these then new missiles were directed laid down their arms.

Having said this much in favor of war rockets, we are to be understood as vindicating their claims to utility, even though no better than Sir William Congreve left them; but it is well known that since Congreve's time rockets have undergone some great and advantageous mutations. Amongst these we must not forget the increased accuracy imparted to rockets by the various devices of Mr. Hale, who, in doing away with the stick altogether, and imparting rotary motion by tangential fire-vents, accomplishes a result exactly similar to that effected on shot or shell by a rifle gun, and with similar intent. Practically, we know full well that Mr. Hale has achieved a certain accuracy of flight at the sacrifice of other advantages already conceded to rockets. A Hale's rocket, to accomplish its intended flight, must be fired at a large angle, which, of course, implies the disadvantage of a high trajectory. Again, with Hale's rockets, the ground volley—a mode of discharge most efficacious against cavalry—must be abandoned, at least under the majority of circumstances. Conceding to Hale's rockets the merit of accuracy beyond that of other rockets, these weapons must still be excluded from calculations in respect to some further developments of the general war rocket system, and that for a reason which will presently become apparent. We are of opinion that no war rocket has yet been made to work in accordance with the true genius of the arm, as impressed by a long course of discovery since the time of Congreve. If wars must come; if destructive projectiles must be launched; if fortifications must be destroyed, towns burned, and human beings demolished, then the proposition, as one of means to ends, falls within the study of the application of forces. We confess inability, on any ground whatever, to perceive why the workmen who are engaged in this line of business—military men, soldiers that is to say—must be condemned to the perpetual routine of gunpowder, lead, and steel, when other and better means are at hand. A list of combustible and explosive things have been discovered since the time of Congreve, things to which gunpowder at its very best, or worst, is a trifle. Nitro- glycerine is one of these, and more especially to nitro-glycerine do our present observations point. Some people are expectant enough to hope and believe in the discovery of a substitute for gunpowder as a material for gun and shell charges. We are not amongst the number of these. For the above purposes the invention of Schwartz, Bacon, the Chinese, or whoever the real discoverer of powder may have been, is, in our opinion, so good that better need not be desired, and, if desired, could not be found. We have never yet heard of a single explosive body that could be substituted for powder in artillery practice with advantage, and, if even found, the merit of such assuredly will not be in any increase of strength over ordinary powder, seeing that, even now, the old material can even be too strong for the resistance of gun metal. As for nitro-glycerine, even were it less shattering, it could never be used for a gun charge, because of its liquidity. As little could it be used for a gun shell charge, because of inability to withstand the shock of first impact without explosion. Nitro-glycerine, however, could be used for the heading of a rocket. And this being so, again, why not? As well might one urge the forging of anchors with arm-wrought sledge hammers instead of the Nasmyths which have supplanted these baby things, as the continuance of gunpowder—only gunpowder—as a certain means to a certain end, when a better force is available. Let no one suppose we are insane enough to propose the application of nitro-glycerine to rockets as a part of any ordinary armament. If, for example, this dangerous liquid were to be jolted about in ammunition wagons, as ordinary shells are jolted about, it needs no conjuror to predict what would happen. Our remarks apply to specific cases; the capture of a beleaguered city like Paris being one. Since the 20th of September

Paris has been invested, German forces encompassing it all round in a circle of about eighty English miles in circumference. Assuming a deliberate intent to make Paris succumb, if possible, then the case becomes one of means to ends. Its consideration is as free to speculation as the boring of a tunnel or the blasting of a rock. None better than the Germans know that to destroy any one of the French forts by the strongest artillery now in the field is practically impossible. Their only hope of success—a hope that at great cost of life may perhaps be realized—is that by the accuracy of their rifled breech-loaders they will be enabled to silence the French batteries though actually firing through the openings of the casemates. As for battering down the forts by hitting the structures at random, the Germans might as well fire apples or oranges at them as the heaviest shot or shell they possess. This proposition granted, we come to an important consideration—one that tends to equalize the accuracy as between rockets and rifled artillery. Handicapping rockets against artillery, so that a rocket hitting anywhere on a structure should count for the same as a bull's-eye made with rifle shell, then on which side would the preponderance of accuracy lie? Might it not lie on the side of the rockets? At any rate, nitro-glycerine could only be projected as we indicate, and for the purpose Hale's rotary rockets are inapplicable, inasmuch as their spinning motion would be sure to explode the charge. In suggesting this mode of attack we make no sort of apology to those false humanitarians who urge the barbarity of the means. Again and again has the axiom been enunciated until universally accepted, that, in proportion as the means of destruction have received development, so have the aggregate horrors of war decreased.

THEORY AND DETAILS OF CONSTRUCTION OF METAL AND TIMBER ARCHES.

By M. JULES GAUDARD.

From "The Artizan."

Elastic arches supporting a road or railway were connected to the horizontal platform by pillars and filling pieces, occupying the spandrels. The office of these parts was to transmit the load of the platform to the resisting arch; no other function was usually attributed to them, and the arch was the important member on which the whole rested. The spandrel, however, forming always a rigid filling or system, contributed powerfully to increase the resistance of the structure, so that it would be justifiable to consider as the chief member, not the isolated arch, but the framework, more or less complex, constituted by the arch, the spandrel filling, and the longitudinal horizontal piece placed at the level of the platform. Under this point of view, the arch might be assimilated to a chain of articulated segments, presenting two modes of calculation which were severally examined. In the articulated system it was necessary to choose a single triangulation, where every piece was essential; for otherwise, if, for example, two diagonals were introduced in each bay, the calculation would become indeterminate. At the summit, the two half-spans were joined by a simple point of articulation, like those of the other summits of the triangulation, while the longitudinal horizontal piece was useless in theory; and in practice it would be desirable to provide it with a free sliding joint, in order that nothing might impede the expansion of the fixed portion. Under these conditions, the elements of statics furnished easily the stresses on all the pieces, of which an example was given. When the stresses in the various parts of the arch or of the longitudinal were known, the stresses in the spandrel bars could be deduced by simple graphic decompositions, based on the equilibrium of the summits of the system. Of this also an example was given, with further calculations. For a determined fixed load there might be given to the arch the form of a funicular polygon, a figure of equilibrium such that the articulated chain might maintain itself in position without the intervention of the other pieces of the framework. In a bridge the load varied, but it was desirable the figure of the arch

should approach that of equilibrium corresponding to the complete load. This form would be the curve called the catenary for an arch of uniform section carrying only its own weight, and the parabola for an arch loaded uniformly per unit of length on a horizontal line. This latter was the case in suspension bridges, and also in bridges with compressed metallic arches, for the weight of the arch and the spandrels had but little influence, proportionately to that of the horizontal platform and its test load.

The second mode of calculation referred to rigid arches, and consisted in restricting the spandrels to simple supports for transmitting the loads. The arch was then more strained, and ought to be rigid, for the funicular form only gave an instable equilibrium, corresponding to a particular state of the load. As soon as this state was changed, the arch no longer suffered simple compression, but was disposed to bend, *i. e.*, to change its figure. In an arch of masonry, the effect of the mortar was neglected, and the voussoirs were regarded as blocks placed in juxtaposition without adherence, having the power of pivoting one on the other, round the edge either of the intrados or of the extrados; that was what was called a system of alternative articulation. The centre of pressures, *i. e.*, the point of application of the resultant of the elementary reactions of the joint, was considered for each joint. The locus of these centres, or the curve of pressures, ought not to pass outside the thickness of the arch, or the pivoting of certain of the voussoirs would take place; the curve ought even to keep within a zone more limited than that of the arch, for fear of endangering the crushing of the stones. An elastic arch was subject to other conditions. If the connection was very good, as was (or ought to be) the case with plate iron, the arch formed an entire piece, suitable to resist both tension and compression. If it was treated as an arch by the curve of pressures, this curve would no longer be required to remain within the arch. When the arch rested upon the abutments by an extending sustaining surface, being keyed by a range of wedges, there was nothing to prevent certain of these wedges being driven tighter than others. This would then modify the point of concentration of the thrust upon the abutment, and consequently also all the other points of the curve of pressures. Hence arose the uncertainty which generally attended the method of the curve of pressures, these pressures only being determined by arbitrary data in regard to the original keying up, or the yielding of the materials. The author considered the proposal to provide a metallic arch with three pivots, or hinges, one at the summit, the other two at the supports; but hitherto, so far as he was aware, no one had ventured to apply three pivots to large works. M. Mantion had, however, employed two pivots at the supports in an iron bridge of the St. Denis canal, and the effect of such a system was examined. The theoretical calculations of deformation might be applied with confidence, where the arches consisted of a single piece of homogeneous metal. Arches in solid wrought-iron plate might be considered to belong to this category, the metal having been well worked, and the connections being as solid as the continuous parts. The theory of these arches had been the object of the researches of M. Bélanger, and subsequently of M. Bresse, who had entered into great detail respecting them in his treatise on Applied Mechanics (Stabilité des Constructions). An explanation of his principal formulæ was then given. The author next proceeded to consider the details of construction of arches of different materials. He remarked that structures in timber were the most economical in many countries, but their durability was limited. The principal type of timber arches appeared to be that inaugurated at Yvry (Seine) by M. Emery, where the arches were composed of strong pieces of carpentry superposed to the number of three, for example. But it was preferred in many cases to leave open the intervals between the several pieces, in order to allow better ventilation, and to prevent them from heating; and further, because this plan gave an increase of depth to the arch, and consequently a more ample field to the oscillations of the curve of pressures. Certain timber bridges presented a compressed arch, a tensile tie-bar, and vertical connecting-rods, a system which was allied to the bowstring form. The flat arches of Wiebeking (Bavaria), and those in thin layers of planks superposed of Emy, would appear only suitable for roofing purposes, being too subject to deform-

ation for bridges. Among the American forms of trellis framework for straight beams, capable of competing with arched openings, the system of Howe, having iron vertical tie-rods, deserved special mention. Cast iron resisted compression well, but tension badly. It made good arches in the cases where the curve of pressures did not pass out of a certain central zone, and where the flexure was nothing, or insensible; and on the condition that there were no powerful vibrations, *i. e.*, that the dead weight was large compared to the moving load. This last consideration led, in the case of railways, to the spreading of a thick layer of ballast on the platform, in spite of the increase of load resulting therefrom. Wrought iron was preferable to cast iron, notwithstanding its higher price, whenever there was reason to fear the effects of flexure in certain parts, or when it was desired to make a light structure, without loading of ballast. There was also an opportunity of adopting pivoted supports, and of calculating the thrust according to the theoretical deformation. However, this conclusion was not absolutely true for trellised arches, which it was necessary to use in the case of very large spans. Such, for example, was the bridge at Coblenz over the Rhine, consisting of three arches, each 317 ft. span. In general, a solid plate web was preferable to trellis-work for arches of moderate dimensions. In effect, the flexure was small, and the longitudinal pressure much predominated; the solid plate acted, consequently, more usefully than in a straight beam, which presented neutral fibres. Moreover, it would only be necessary to employ rivets at considerable intervals in the parts outside the joints. To satisfy the most advantageous condition, viz., a large moment of inertia, without too great depth, it was desirable to adopt for the section a double T with large wings. For large openings, however, a box section appeared to be preferred. The lateral stiffness would depend essentially on the cross framing which connected together the different arch ribs of the same span. Where this resource was wanting, *i. e.*, where an isolated arch rib must maintain itself alone, the oval section analogous to that of the arches of the bridge at Saltash, presented itself as one of the most favorable. Wrought and cast iron might be associated in the same work. This combination had been adopted in a bridge of three arches constructed in the park at Neuilly, near Paris, many details of which had been suggested by the new Westminster Bridge. All the pieces essentially under compression, *i. e.*, the spandrels and the portions of the arch near the abutments, had, for the sake of economy, been made of cast iron, while the central portion of the arches and the longitudinal bearers of the platform were of plate iron. Arched bridges were, on principle, often more economical than those formed with girders; they admitted better of an augmentation of the dead weight, for the purpose of deadening the vibrations and increasing the probable durability. But it was necessary that sufficient height should be available, and that the abutments should be able to resist the thrust. When the work was low and the ground solid, it was easy to give the abutments the necessary stability, without too much expense. The compression, tending to close the molecules of the metal, appeared to promise to such works a longer duration than would be due to pieces in tension, which threatened, after a long period, to be subject to enervation. These considerations in favor of arched bridges were, it is true, somewhat counterbalanced by the greater complication of the forms. Bow and string bridges were, as the words implied, arches provided with a tie-rod which received the thrust upon the extremities, without the intervention of supports; so that the abutments were freed from the effect of these thrusts, and only exerted reactions in a vertical direction. The most remarkable example was the bridge at Saltash, of two great spans of 456 ft. each. The arch, being single, had to be kept at the two ends at the height above the roadways necessary to leave a free passage for the trains; and this led the eminent designer, Mr. Brunel, to adopt a curved tie, and to suspend the platform at a lower level. When there were two arches, one on each side of the road, there was nothing to prevent their extremities descending to the level of the platform; the tie was then straight, and being strengthened in order to serve as a longitudinal bearer, it might support the roadway. An example of this disposition was the bridge of Audenarde, on the Scheldt.

In conclusion, the author referred to a work he had published in 1865 ("Etude

comparative sur les Ponts en Fer,") in which he had given formulæ expressing the stresses on the various parts of bow and string girders, as well as the comparison between this and other systems of construction.

BOOTH'S PATENT RAIL.

This rail consists of an iron base with a steel cap, united to the base, not by bolts, screws, or rivets, but simply by clamping. The iron bar is rolled to the required form and weight, after which the steel cap, having been rolled of the proper form and length, is properly tempered and placed upon the cold iron base. The two are then passed through the Compressing machine, which presses the cap down upon the base and clenches in its side. A good fit and a fast hold are thus obtained, with a powerful shrinkage.

To remove the steel cap for refitting or other purposes, the iron base is firmly secured, and by a hook on each side of the cap a separation is formed at one end, and followed through by rolls the entire length of the rail.

Patents have been obtained upon this rail in the United States, Great Britain, France, and Belgium. By the original patents there is secured to the inventor the sole and exclusive right to manufacture, use, and sell rails, composed of the iron body and steel cap, when the latter is rolled and shrunk on the body in such a manner as to unite the parts closely as a unit or whole, but still allow them to be easily separated and replaced. More recent patents secure the use of the combination of the cap and base, with depressions or indentations in the base, as found desirable.

This feature of clamping the cap around the head of the iron base, is thus recognized by the Patent Office as a new and original feature. Other compound rails have been made of iron and steel, but in all cases the steel and iron have been united by rivets, bolts, or welding. These have all proved defective. Besides other causes of displacement, the variation in climate of 125 deg. annually, expanding and contracting the iron and steel differently, has been found sufficient to cut off the rivets and tear asunder the welding. Booth's arrangement obviates this difficulty entirely, by allowing the cap to slide sufficiently on the rail without displacement or injury to either material.

In this form of rail are combined, it is believed, all the advantages of both iron and steel rails, with others that would alone render it superior to either. Notwithstanding the prevailing tendency to extol the merits of the steel rail, there is no doubt that the iron rail possesses some obvious advantages over its rival, and further experience of steel may show that it has others. Its obvious advantages are:

1. Cheapness of cost.
2. Greater elasticity under travel.
3. Capability of being made over.

To offset these, there is claimed for steel rails so much greater durability as alone to render them more economical on the whole; but whether this will prove to be the fact in view of their special disadvantages, can only be determined by experience. These disadvantages are:

1. Greater first cost.
2. Greater rigidity under work.
3. Liability to break.
4. Incapability of being made over.

The 1st and 4th of these disadvantages are of obvious weight in the consideration of economy. The extent of bearing of the 2d and 3d cannot at present be accurately estimated. There can be little doubt, however, that the greater rigidity of the rail (which is apparent, even to the traveller over it, by the harsh and disagreeable grating sensation it produces) depreciates the rolling stock more rapidly. The granite ties or stone work upon which railways were first laid, are, for this cause, now universally discontinued. With regard to the breakage of steel rails, we have some evidence furnished in a late report of the President of the Michigan Central Railroad Company, James F. Joy. He says (see Report, 1868, page 7):

"Three miles of steel rails have been laid, and thus far they have hardly borne the test, having been found more liable to break than iron."

These rails are of the best English made

Bessemer steel. Also, in the report for 1868, of the President of the Chicago B. & Q. R. R. He says:

"We have laid about three miles of steel rails where they will be subject to the greatest wear, in order to test their quality and durability, as compared with iron. The result thus far has not been such as to encourage the Board in an extended use of it in the ordinary track of the road."

Thus it appears that the only certain advantage that the steel rail possesses over the iron, is its greater durability.

Our next inquiry will be to compare the Booth rail with both the others, in respect to the qualities above considered:

1. Cost.—The first cost of the Booth rail is much less than that of steel, though of course, greater than iron. But it has been suggested that *in case* steel should be hereafter made as cheap as iron, that this advantage would be lost. We contend, however, that even in such an improbable event, the Booth rail could still be made cheaper than the steel, inasmuch as vast quantities of old iron rail, from which it could be made, would then be inevitably on the market, at prices much below their usual standard of value. This can be worked over into the iron base of the Booth rail, and the whole rail thus be made at a less cost than steel rails from new material.

2. Durability.—Supposing the cap to remain firmly in its place (a point which we shall consider hereafter), it is evident that it will wear as well and as long as any other steel surface. The thickness of the cap being about one-half an inch (and more if desired), it will only wear out by the same abrasion of surface as would render a solid steel rail useless, especially as this abrasion would not be uniform but irregular. The *first* wear of this rail, therefore will be equal to that of the steel rail. What that wear would be, may perhaps be pretty nearly estimated. English experience establishes the fact that a steel rail will outwear seventeen iron rails in the same service. It is also stated that it takes 11,000,000 wheels to reduce a steel head 7 lbs. to the yard—there being no lamination, but a uniform wearing away, as by friction. If these reports are true, it would take forty years to reduce 7 lbs. to the yard, upon the straight portion of any principal railway in the United States.

The Booth rail, as now made, has 15 lbs. steel to the yard, and after a uniform reduction of 7 lbs. to the yard, it would still be serviceable.

In point of exemption from liability to breakage, it is evident that its advantages are at least equal to that of the iron, and therefore, as we shall prove hereafter, superior (in all probability) to steel. We are now considering economy merely in the light of the durability (or life) of the rail. But this exemption from liability to breakage has a more important bearing on the question of economy, by its result in freedom from accident. And we shall, therefore, examine the subject further, when we come to consider the special advantages of the Booth rail, with reference to safety.

3. Capability of being worked over.—In this respect the Booth rail enjoys a great superiority. The steel rail once discarded, is useless; and even the iron rail must be taken to a distant rolling mill and re-rolled at great expense. But the Booth rail can, by machinery that will not cost over $15,000, and which every railroad company can afford to own, be at once re-capped at a comparatively small expense.

4. Elasticity under Travel.—The base of the Booth rail being of iron, exhibits the same advantage in this respect as an iron rail. The extent of this advantage in its effect upon the wear of rolling stock, as well as upon the comfort of the travelling public, we have before suggested, can only be fully ascertained by experience. When it is remembered that the steel rails in use are three times as stiff between ties as iron, it will be apparent that the effect of this increased rigidity *may be* considerable, and the advantage of an iron base is, therefore, well worthy of consideration.

Other Special Advantages—Safety.—It thus appears that the Booth rail possesses the combined advantages of both the simple rails, and that in the important quality of economy, it is far superior to either. Is is also superior to either in the no less important quality of *safety*, for, being a duplex rail, it cannot break unless flaws in both parts should come together, which is to the last degree improbable. Hence either part may break

without danger of immediate accident, giving an opportunity to substitute a sound for the broken rail. The numerous accidents, some frightful, and all expensive, that have occurred during the last few years, from broken rails, will attract to this advantage of the Booth rail, a serious attention.

It would seem that the steel rails are more liable to breakage than iron. Much skill is required in their manufacture, and there is thus more danger of flaws, or burning, or imperfect temper. Many have, in fact, broken from being made too hard, and it is certain that in casting the ingot of Bessemer steel, many crack transversely. These flaws, in many cases, even if extending half through a piece of steel (60 lbs. to the yard), would hardly be discovered, even by a sledge-hammer test. Yet, with a 40-ton engine, on a cold night, there would too probably be a different result. Flaws might also occur, and undoubtedly do, in the Booth steel cap, but as this weighs only 15 or 16 lbs. to the yard, the test of the hammer, which is always applied before its application to the rail, and the further test secured by the process of rolling on the cap, are sure to discover the defect, and even should these both fail, there is, as already observed, an additional security in the strength of the iron base. It is a well known fact, that iron and steel united, cannot be broken as easily as the same size piece of either separately.

In this connection we may add that the strength of this rail has been practically tested in comparison with iron and steel rails of the same weight, under a powerful press, and shows a marked superiority over both. Attempts to break it by repeatedly bending it in opposite directions proved unavailing.

We have already shown that any railroad company can take up and repair its own rails, at moderate expense, but there is more to be said on this subject. In case a rail fails to wear evenly, or becomes battered or defaced at the ends, there is no need of losing it like an iron or steel rail, or even of taking it up, but the defaced portion can be at once cut out by means of a milling tool, and the rail re-capped in that part without removal.

COAL MINES IN CHINA.

From "Engineering."

The following particulars relative to the coal mines in the neighborhood of Kelung, near Shanghai, have been drawn up at the request of Her Majesty's representative at the latter port. The mines at present in working order are 46 in number, and occupy a tract of country covering an area of some 30 miles to the eastward of the town of Kelung. They produce an aggregate, in the year, of 300,000 piculs, or 17,142 tons, a third of which is exported in 200 junks from Kelung. Some 1,300 miners are employed, whose wages are at the rate of 40 cents a day per man, while those of the porters carrying the coal to the water's edge, average 30 cents. The range of hills in which the coal is found in abundance touches the seaboard at a small bay called Pa-tow-ah, known in the charts as Coal Harbor, 3 miles distant from Kelung. The distance from this bay to the nearest mine is $\frac{3}{4}$ of a mile up hill, down which the coal is brought by porters, and taken thence in junks to Kelung for sale. A navigable creek called Tienlias Kiang, $2\frac{1}{2}$ miles in length, connects the more remote or "inner mines" with Kelung itself. The cost of transport from Coal Harbor to Kelung, by water, is from \$1.50 to \$2 per 100 piculs, it being influenced by the state of the weather; while that from the inner mines along the creek to Kelung is about \$1 per 100 piculs, the boats used carrying 150 piculs or 8 tons. The price of coal at the pit's mouth is quoted at \$13, and at Kelung it ranges from \$16 to \$22 per 100 piculs, that is, from 13s. to 18s. per ton, the latter price being paid for the very best picked coal. The coal is found within a very few feet of the surface, and the mines are, in most cases, worked into the side of the hill in nearly a horizontal direction, and the water which accumulates therein is thus enabled to run off easily through the entrance. In some instances, however, the strata dip slightly inwards, and then pumps, on the same principle as the chain pumps seen in the paddy fields throughout Southern China, are employed, which,

worked by 3 or 4 men, raise about 25 gals. of water per min. This contrivance answers well enough for the little drainage necessary. The depth of the mine hardly exceeds 500 yards, as, when the vein is worked through, it is left ; its height at the entrance is from 3 to 20 ft.

The lamps used by the miners are merely small saucers with oil, and a wick protruding over the side, one end of which is lighted, and the saucer placed in a niche in the side of the mine. Fire-damp seems unknown, though no special means are employed to secure ventilation. The proprietors of the mines are, as a rule, the descendants of the first settlers, after the expulsion of the savages ; the heads of the clans, some 20 years ago, petitioned the officials to prohibit the working of the mines, for fear of the ill-luck which would, as they said, result ; but the payment of a slight tax sufficed to overcome any opposition at that time. The obstinacy of the officials, combined with the want of proper mining ability, has hitherto impeded the working of the most productive beds of coal, said to lie beneath the level of the river leading to Kelung. The proprietors state their unwillingness to sell or lease the mines to foreigners without official sanction, and their capital does not admit of their employing foreign machinery. The tax levied on the exportation amounts to $2.40 per 1,000 piculs, or 2½d. a ton, the picul being estimated at 128 lbs. The chief faults found with the Kelung coal are, that it burns too quickly, and generates an enormous amount of smoke. If properly mined, however, these defects are said to disappear ; and some has been obtained which was considered to be but 25 per cent. inferior to the best Welsh coal.

ON THE SELECTION OF BUILDING SITES.*

From "The Builder."

Buildings are, of course, constructed on all kinds of sites ; but for many reasons modern towns generally occupy valleys, and are thus distinctly contrasted with towns of other days, which were much more commonly, and for equally good reasons, perched on eminences. Valleys now traversed by rivers are far more convenient than plateaus, as more accessible both by land and water, and if less safe in a military sense than plains in some respects, they are much more so in others. But whatever the reason, it is a fact that all important and large cities are on or very near large rivers. Thus the condition of the rocks on the surface of valleys has important significance.

It may be assumed, in the present state of geological science, that all such open valleys as now form or contain the beds of rivers, have been reduced to their present shape, and have derived their present condition from the passage of water through them. The beds or bottoms of the valleys have been cut out by water, the transported material with which they are covered has been moved by water, the cliffs or slopes of the enclosing hills, at whatever distance, have been brought into their present state by weather action, and small as the stream may be that runs along a narrow channel in a winding course between these cliffs or slopes, it has been sufficient in the course of time to bring about the result we see before us. All that lies immediately beneath the surface in the valley, often to a great depth, consists of material removed very gradually by this water, while below that there is often another deposit of water-transported material, consisting of clay, stones, and sand, due perhaps to ancient glaciers, or left behind by icebergs that have floated over or have been stranded upon it when many fathoms below the sea level. Sometimes there are streams entering the main river from side valleys, and each of these again has formed its channel and left its mark. The more sluggish the main stream, and the further it is from its source, the greater in proportion is the effect of such feeders. When they are torrents they sweep all before them, and deposit large stones with smaller gravel, clay, and sand. When they have had a more even course,

* From a paper by Professor Anstead, F. R. S., read at the Royal Institute of British Architects.

they deposit fewer large stones and more mud and sand.

From this account of the history of river deposits, given in a very few words and requiring to be varied in detail for every stream without exception, you may understand the nature of the material that you have to deal with in preparing foundations for a large and massive construction, in almost every part of England where such buildings are likely to be erected. The clay you find may be alluvial clay deposited by the stream, or it may be boulder clay left behind by ice. It may thin out at any point, and give place to gravel, to loose stones, or to fine sand. Beneath it may be a quicksand. A certain number of tons pressing on the square foot of surface may and will cause the clay to slip away from the sands, or the run of an open drain through such sands may, by removing them, remove all support. When in the bed of the main stream, there may be a very regular deposit of clay, capable of supporting any weight that could be put upon it, but the intervention of one of the old and forgotten tributaries may have cut away part of this clay for an interval, or prevented its formation, and thus one part of a building may be on a good clay and another part on loose shifting sand.

It is exceedingly important that the exact physical conditions of the formation of the alluvial beds of rivers should be clearly understood by practical men. It is by no means the case that the present bed of a river is the only part where loose and uncertain material exists, nor is it at all necessary to assume any change of level, still less any great convulsion of nature, to account for the phenomena. They may be studied in every valley where the stream is left to take its natural course; but in England, and in many other countries where land is valuable and cultivation carried on extensively, the rivers are never left to themselves, and, therefore, the changes that explain and illustrate these conditions are not perceived. In a natural state a river rarely follows the same course through its valley many seasons in succession. Either it chokes up its old bed and steps aside to form a new one, or, owing to a torrent, it cuts itself a new course altogether, and leaves the old bed dry. All our river beds have been formed in this way. It is not that the quantity of water brought down varies much, but that the circumstances change, and new channels are cut, the deposits of course shifting. The whole width of the valley through which a river runs is of the same nature, and the deposits are due to the same cause. Hence, the variety in the foundations in different parts of the valley far removed from the present course of the stream, which has not, perhaps, been allowed to shift for many centuries.

But in addition to ordinary alluvial bottoms resting on clay, limestone, or sandstone, as the case may be, and consisting of the usual admixture of sands, clays, and river gravels, are the instances in which the river valley has been ploughed out by the action of the ice, and has received large deposits of boulders, boulder clay, and the usual accompaniments of fine and course sand and gravel. Gravels are frequently found at levels very much above the bottom of the valley, and they not unfrequently even cap the hills through which the river is cut. The same kinds of gravel often occupy the valleys themselves.

Excellent as gravel is as a foundation when in sufficient quantity and uniform in texture, it can hardly be trusted unless its history be known. The gravels called diluvial are often comparatively free from loose sands and clays, and are then excellent for every purpose required by the architect or engineer. They are sound, well drained, healthy, and generally yield water at a small depth. But it is not so with the gravels occasionally found with boulder clay, nor with ordinary river gravels, and thus, as I have already pointed out, the history of gravel is an important inquiry when it is proposed to construct buildings upon it.

Natural drainage is very important in all large buildings. Without this, even if the foundations are sound, moisture will rise up by capillary action through almost every variety of stone and brick, and will in time deface the building and increase the action of weather on the surface. Certain rocks drain naturally, and are safe. Others may be drained with little difficulty, and may be made safe. Others, again, will tax the ingenuity and experience of the most accomplished architect, and will, after all, be only partially cured. There cannot be a

doubt that in this latter, and also in the second case, the constructor would be greatly assisted by knowing the nature of the enemy he has to deal with, and this can only be done by a knowledge of rocks generally and of the local geology.

Very important questions arise in reference to the relative influence of certain rocks on the sanitary condition of the buildings erected upon them. Thus, in a general sense, it may be considered as proved by experience that clay soils and other impermeable material near the surface are less healthy than well-drained sites, and more liable to attacks of fever, and that permeable soils and gravel are dry and healthy. There are, however, important modifications of this view, dependent on the subsoil and underlying rock, which are often out of sight and below even deep foundations, and here a knowledge of geology becomes necessary to the architect. It is well shown by Professor Pettenkofer, of Munich, that in certain cases where bands of clay intervene in gravel, the presence or absence of fever in the population corresponds exactly with the existence or otherwise of these impermeable deposits. In other words, even where the general subsoil enjoys a certain amount of natural drainage, the healthiness of the site depends strictly on the condition of the rocks at a considerable depth, and that stagnant subsoil water, even when its presence cannot be detected by ordinary observation, makes itself felt in a very serious manner.

In speaking of the applications of geology, I have avoided the mention of particular rocks as much as possible, because it is not so much the rock as its condition that affects the practical man. I have known granites porous and absorbent, limestones compact and non-absorbent, sandstones offering every possible variety in every respect, and even clays very different in different places. What is wanted is such a general acquaintance with the principles of stratification and the nature of rocks as shall enable the architect or builder to make the best use of the conditions he has to deal with. I cannot lay down rules that can be made use of without further trouble ; I can only point out the key which will unlock the difficulty in each individual case, if it is applied properly and intelligently.

Water supply from springs, either at or moderately near the surface, is a very essential matter in the case of buildings intended as habitations removed to some distance from pure running water. But it is now well known that however pleasant clear spring water may be to the taste, it is capable of containing, and does in certain cases contain injurious ingredients sufficient to render it a fatal poison. There can be no doubt that certain superficial deposits and certain rocks are liable to induce this state in the water, while others are not. It is evident that the causes of events of this kind should be known to the architect, and it is highly desirable that he should be acquainted with the theory of springs, at least of such as are likely to affect buildings. Absorbent gravels resting on non-absorbent rocks may be expected to introduce poison into water when the ground is liable to be covered with decomposing animal or vegetable matter, or with sewage, for the rain entering them cannot fail to carry in water loaded with as much of such impurities as it can contain. Such of them as are soluble in water will certainly therefore mix with it, and render unwholesome all the water pumped from the bottom of such a deposit.

On the other hand, where water has a free exit from rocks, it is almost impossible that such injury can take place to any great extent. Land springs and Artesian springs from basins are dangerous. Springs from hill sides, or Artesian springs reaching water tapped in its progress to an outlet, are generally safe. How is it to be known what is the nature of the springs without some reference to the science of geology, and some knowledge of the laws of superposition of rocks?

The whole subject of the weathering of rocks deserves the careful study of all who have to deal with stone and brick. All material, without exception, is affected by exposure; but while some will remain almost unchanged, and even hardens when left to the action of the air, other kinds will at once decompose and rot. It is not always the hardest that is the best. This is especially the case with flags or stones splitting with parallel faces. Many very good flagstones are formed by the exposure of quarried and squared blocks during one winter, and then in the following spring splitting the mass by wedges in the

cracks indicated. If left longer, they can no longer be split with advantage; and after a time it becomes impossible to split them at all. Something of this kind happens with all stones. After being quarried, stones are for some time in the state called green, and after exposure to a certain extent they are said to be seasoned. In the latter state they are regarded as fit for use; but, after all, it is doubtful, without experience, whether they will be permanently sound. It is evident that if the architect and builder knew more of the history of stones he would be able to use them to better advantage.

The study of stones in the quarry, and a careful examination of the effects of weathering and disintegration by the action of rain and frost of the same stone in the immediate neighborhood, whether naturally exposed or placed in buildings of any kind, combined with a knowledge of the chemical composition, the peculiarities of aggregation, and the natural history of the stone itself and the beds with which it is associated, will very often suggest to the intelligent observer its probable weak points for the special service for which it is designed. There are accumulated stores of information of this kind that should be familiar to all who have to decide on the selection of stone, and it should be remembered that stone is in the nature of things an altered form of a very miscellaneous deposit, and that, without especial care in selection and placing, it is next to impossible to secure a large quantity of perfectly even quality.

You will observe that I have included a great variety of details as included within the very important subject of building sites, but I trust you will not think that I have done so without sufficient reason. I am well aware that in modern constructions beds of concrete play an important part in forming artificial foundations, and are much trusted to in keeping out damp and preventing unhealthy miasma. I wish to point out that, however useful such an avoidance of the difficulty may be, it should not be trusted to implicitly, and I think it would be easy to show that there are cases where the danger and mischief would only be postponed for a time by such contrivance, and would reappear and act with full force when by irregular pressure on a bad and shifting subsoil the concrete becomes cracked and crushed long before the time has come when the building would begin to fail by reason of age and general wear.

I assume as entirely beyond discussion, that in the exercise of his profession the architect desires only to do justice on the one hand to his own inventive genius, skill, and reputation; on the other, to the highest interests of his client. I have endeavored to show that in order to do this he must inform himself concerning, and be to some extent familiar with, the principles and applications of the science of geology as now understood. He must from time to time call in the aid of this science to decide matters of vital importance, and he cannot do so properly without making them a subject of serious and special study. I have not entered into details, as they could hardly be fitly discussed in this place, but I have endeavored to illustrate and explain the principles to which I think your attention as architects should be directed.

Since this memoir was in type, my attention has been directed by my friend, Dr. Letheby, to a pamphlet by Dr. Pettenkofer, in which attention is drawn to the great influence of subsoil and rock on certain diseases, especially cholera and typhus. Dr. Pettenkofer points out that in the case of Gibraltar and Malta it was proved by British statistical returns that at a time when cholera was raging over a large area, there were certain small localities that escaped. On investigation it was found that, whereas the subsoil to a great depth, and, in the case of Malta, the rock, was eminently porous and permeable, the spots that escaped were situated on impermeable clays.

There can, indeed, be no doubt that the health of a town is greatly influenced by the condition of the rock and soil on which it is built, and that generally a moderately porous soil, admitting of the removal of moisture by drainage, is conducive to health, especially in a damp and comparatively cold climate, like that of England; and also that with us gravel and limestone as subsoil and rock are healthy as well as pleasant. But it is equally certain that where the underlying rock is deep and permeable, admitting of a considerable alteration of level of that surface of permanent wetness which is sure to exist at some depth or other under

such circumstances, but which varies with the season, the result may be different, and it may require both knowledge and judgment to decide as to the relative value of sites, even with regard to water only. It is also true that wherever there is a great collection of human beings, living over a permeable soil and rock, the effect of the accumulation of refuse and sewage cannot but be felt in the course of time. The water percolating from the surface will carry down organic matter, and this in time will make itself felt by generating unhealthy vapors occasionally reaching the surface.

But there is another question to be considered, which in warm and dry climates rises into great importance, and with regard to which the observations of Dr. Pettenkofer are very suggestive. All rocks are capable of absorbing, and therefore usually contain a certain quantity of atmospheric air, either in its normal state or replaced by other gases. No doubt a certain change in the constitution of the gases absorbed may take place, in consequence of an action well known to take place in porous and spongy solids when mixed gases pass through them. The quantity of air or gases contained in all rocks must vary, and must be affected by changes of weather. During dry and hot weather large quantities are given off, and during colder weather re-absorbed. In rocks, then, that contain much air, either in consequence of their great absorbent power, or their mass when there has been received into the body of the rock by percolation from above any quantity of organic matter, and this organic matter has become putrid, the gases given off during hot summer days are liable to become dangerous miasma, and when cholera and fever are prevalent, are especially liable to communicate infection. I cannot but attribute to this cause the extremely bad sanitary state of some districts in the Mediterranean—healthy enough so long as there is rain, but poisonous in the dry autumn; and in these cases I can easily understand that the intervention of even a small and thin band of clay may be a source of safety, and the more so the nearer it is to the surface.

I need offer no apology for pointing out these facts and inferences in a memoir on the subject of building sites, and of which the application of geology to architecture is the professed subject. Sanitary considerations connected with, and arising out of, topographical and geological positions, can never be dissociated from the practice of architecture, and I am sure you will agree with me that all knowledge that can help to a conclusion in such matters is not only desirable, but ought to be considered indispensable to the architect.

ON THE STRENGTH OF LOCK GATES.

By WALTER R. BROWNE, Assoc. Inst. C. E.

From "The Artizan."

The author first alluded to previous communications on the same subject by Mr. Peter Barlow and by Mr. Kingsbury, in the proceedings of the Institution, and remarked that Mr. Kingsbury, in arguing in favor of cylindrical gates (*i. e.*, such as when closed formed a single arc), had assumed the pressure on such gates to be uniform throughout the section, which was not necessarily the case. The external forces common to all varieties of gates were then obtained by the ordinary principles of geometrical mechanics. The most important and complicated case, that of a cambered-iron-plate girder, was next taken, and it was shown by analysis how to find the strains, and consequently the area requisite at any part, first of the central section, and subsequently of any other section of the gate. The result was an equation between five variable quantities, so that four of these being fixed by other considerations, the fifth could be thus determined. These quantities were the two flanges of the girder, the depth and thickness of the web and the camber. The application of the result to the ends of the gate showed that the area of the front flange (or that away from the water) and of the web should be greater at the ends of the gate than at the middle. The question was next considered, how these other quantities should be fixed. The dimensions of the web and front flange

were left for practical considerations. It was shown how, for a given pair of gates, to determine the camber, so that the back flange (that towards the water) should be as small as possible. Lastly, the proper value for the rise or sally of a pair of gates was considered. It was shown that, theoretically, the rise should be such that the gates met at a right angle, but that there were practical objections to this which seemed to reduce the proper angle between the gate and the span to from 25 to 30 deg.

The paper closed by remarking that the double skinned gates, now in favor, were heavier than appeared by theory to be necessary; that wooden gates were short-lived and could not be given much camber, and that a wooden skin, supported by girders at intervals, would appear to be the form best adapted to the requirements of theory and practice.

THE BRITISH NAVY IN 1871.*

The difficulties of European politics all point in the direction of war. We may have hugged to ourselves for awhile the comfortable delusion that our insular position secured us exemption from attack; but we have now to confront realities instead of probabilities, and are compelled to ask seriously, as a question of moment, "Are we ready to meet any eventuality."

The temper of this country has been tried and has not been found wanting, for all classes of Englishmen feel that, if it is necessary to go to war to defend our national honor, fight we will; and although there is an impression abroad that we are solely engrossed with our commercial interests, and too peace-loving to draw the sword, there is a latent force and determination to resist dictation and avenge insult, which, when roused to action, would prove that the might of England, if it has slumbered, has lost none of its puissance, and would be put forth when needful with even more than its wonted vigor and persistence.

The navy constitutes our first line of defence and our strongest force in attack; it is, as it has always been. the right arm of England's power; and never, in our country's glorious annals, have we possessed a more powerful fleet, more complete and efficient armaments, or more gallant and better trained seamen than at the present time.

A retrospect of ten years will be the best way of understanding the present position of officers and seamen in the navy.

Before the days of iron-clads, the force of men required for the navy was much larger than it is now. While in 1860 there were as many as 250 ships in commission, there are not at present more than 200, distributed over foreign and home stations; but whatever has become of the vessels, the officers remain. It is, indeed, certain, that during the last ten years, the ranks of officers have not been much thinned, though the number of men has been gradually reduced. As vacancies have occurred in the ranks of officers they have been filled up, and, as a result, it is found impossible to give them employment. The old days of large squadrons, headed by a three-decker with a thousand men, are over; but, unfortunately for the contentment of the service, these fine old days have passed away too quickly. The naval service has undergone successive changes, during the last ten years, which have left hardly a feature unaltered, and have in each case materially affected the welfare of the British sailor. In the old days sailors were full of frolicksome fun, with a possibility of mischief; a ship would come home and land a cargo of men ready to be fleeced to their hearts' content, and well worth fleecing. The crew of the Hannibal, paid off late at night, twelve or thirteen years ago, included men, each with £50 and £60 in his pocket, who roamed the streets of Portsmouth the next morning without a penny left them. This, however, was not so attractive a sequel to the cruise of the old tar as getting into Devonport and hiring all the cabs in the town for a short cruise round the place, all hands outside, and the inside reserved for any "lubbers" who liked to take them. Happily, those days when sailors were the victims of

* Extracts from a pamphlet entitled "The British Navy in 1871." By Robert Main. London: Smith, Elder & Co.

crimps, are well nigh over, and with them the old seaman has vanished; the old hands of ten years ago are now out of the field; the stoke-hole has superseded the decks and rigging, and the artisan holds a higher rank than the seaman in the navy. Thus, there has not been found much difficulty in reducing the number of seamen, year by year during the last ten years, to something like the limits actually required of service.

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Our navy now consists of nearly 600 vessels, including every class from a cruiser or gunboat to a man-of-war; and there are in active service about 200, now in commission, of which 25 are iron-clads. The most important squadrons in the Mediterranean, the Channel, and the Coast Guard, consist at present of the finest vessels in the navy. It is interesting to trace the progress made in replacing obsolete and useless vessels by those of the new construction; but in reviewing the efforts of the past year to provide new vessels for the navy, two painful circumstances at once confront us—the loss of the Captain and the resignation of Mr. Reed. It is not within the scope of this pamphlet to enter into either of these controversies; they can only be noticed as disasters, marring an otherwise energetic and prosperous attempt to reinforce the navy with efficient vessels. One special point, however, requires attention here, as it is of a very important character.

Shipbuilding in our dockyards had, for many years, been carried on in a fitful, irregular manner; each administration seemed to think itself justified in getting on as well as it could with the ships it found in existence, and when a panic or other causes arose, going in for shipbuilding with violent energy. This fitful policy—arising partly from the rapid and great improvements necessitated by the increased power of the armaments of our war ships—has been, as may well be imagined, the very reverse of what is either economical or judicious. It has led to ships being built in a hurry which were not wanted; to the admission of an excessive number of artisans at one time, and their necessary wholesale dismissal at another; and to the navy being generally in want of ships of the right sort. As evidences of such defects, we have only to refer to the fact of Sir John Pakington finding himself compelled to build, all of a sudden, 15 frigates which became obsolete almost before they were completed; and to the dockyard dismissals of the last three years. Immoderate work, immoderate stagnation of work, and immoderate employment or dismissal of artisans, have been the fruit of this shuttlecock sort of policy. This state of things Mr. Childers has already attempted to set right by laying down what he considers the minimum annual rate at which shipbuilding should be maintained, and by following it out.

After mature consideration, he arrived at the conclusion that to keep the navy up to its due strength in ships, so as to maintain a minimum standard of efficiency, it would be necessary to build about 20,000 tons of shipping annually. This steady increase to the strength of the navy would suffice to supply deficiencies caused by the annual waste or decay of ships, and would obviate the necessity, except in a time of emergency, of resorting to any unusual means for increasing their number. This annual increase he proposed should be divided between the armored and unarmored vessels, by building 12,000 tons of the former and 8,000 tons of the latter class; and with the view of making use of the dockyards and dockyard labor as much as possible, he proposed that about a fifth of the work only should be done by contract. To show how important an addition this annual increase would be to our fleets, I need only state that it represents three new iron-clads, a frigate, a corvette, and six smaller vessels, annually. This would, indeed, be a very satisfactory plan if properly carried out; its cost would be roughly about two millions and a half; in other words, about a quarter of the sum annually voted for the navy would be devoted to the solid increase of its power.

But to understand a little more clearly the advantages of this policy, it is necessary to know, practically, how our navy stands in regard to ships, especially iron-clads, at the present moment. This time last year there were 47 armored vessels of all descriptions, of which 37 were complete and 10 were in course of construction. An enumeration of their names will be all that is necessary, to show in what position we now stand. The 10 new vessels under construction are the Iron Duke, Sultan, and Glatton, at the royal dock-

yards; the Swiftsure, Vanguard, Triumph, and Hotspur, which are being built by contract; and lastly, the 3 new ships laid down by Mr. Childers, the Devastation, Rupert, and Thunderer. This was the condition of our iron-clad fleet a year ago. To show how far the Government has endeavored to give a practical effect to its shipbuilding policy, and what progress has been made during the past year, we can state that of these 10 unfinished vessels, 5 were launched—the Vanguard, Iron Duke, Hotspur, Sultan, and Swiftsure; and, as will be seen by the following statement, 5 new ships were laid down, namely, the Fury, Cyclops, Gorgon, Hecate, and Hydra, all turret-ships; of which 2—the Fury and Hecate—are to be built at the royal dockyards.

We start, therefore, in the present year, with 51 iron-clads, of which 10 are not quite complete; and but for the loss of the Captain, we should have had 52. The finest vessel added to the navy last year is the Sultan, which is not unlike the Hercules, but is superior to it from being able to carry its armament in a way that makes its guns more powerful. The outbreak of war has caused the Government to push forward shipbuilding with great energy during the past few months, and it is by no means improbable that as many iron-clads will be added to the navy this year as were added last year. Great progress has been made with the Devastation, Glatton, and Triumph, and we may expect to hear of their being launched before many months are over.

Before leaving the subject of ships, I ought to notice the launch of the Plucky, the Comet, and Blazer, little gun-boats built like the Staunch, carrying in their bows one gun, mounted and fired after the fashion of a Moncrieff battery. These gun-boats are a great addition to our naval strength; the loss of the gun-boat Slaney, last year, was a misfortune to the service and a loss to the country. It is proposed to build 2 armored gun-vessels at Chatham, the Scourge and Snake, designed probably with the view of acting like the gun-boats on the Seine, near Paris, which did good service in the sortie on the 30th of November; lastly, there are some wooden vessels of various sizes now under construction. The Blonde is an iron screw-vessel, being built at Portsmouth; the Raleigh has just been laid down at Chatham, and is an iron screw-frigate cased with wood; the Robust is an 81 gun screw frigate, on the stocks at Devonport; the Bulwark is an 81 gun screw-frigate, laid down at Chatham a long time ago, which last year it was proposed to convert into an iron-clad, but upon investigation it turned out that the experiment would be very costly and not by any means satisfactory, and the idea has been therefore abandoned. Four small vessels—the Lively, Osborne, Vigilant, and Woodlark—conclude the shipbuilding work which the Government has now in hand.

With respect to our naval armaments, it will not be forgotten that the accident in the Hercules, added to other untoward circumstances, induced Mr. Childers to look closely into the present state of the heavy ordnance for the fleet. Last year he expressed himself satisfied with all guns of a 12-ton 9-in. calibre and under; but suggested that the heavier ordnance for the navy was not satisfactory. The 18-ton gun was not quite trustworthy; but, on the other hand, the 25-ton gun had been proved thoroughly efficient. In other words, while the ordnance of the most powerful and least powerful iron-clads was good, the armaments of the Hercules and Sultan were not altogether satisfactory. Then, again, good as the 25-ton gun was for the Monarch, Hotspur, and Triumph, it is not powerful enough for the new ships now being constructed, such as the Devastation, Fury, and others. For these vessels it has been determined to have at least 30-ton guns, which have yet to be constructed; it is not intended to open competition for guns of this class. The chilled projectiles for the navy are not quite satisfactory, several having burst; competition, therefore, is to be allowed for the best projectile. Captain Palliser, in discussing this question, thought that the failures were not serious enough or sufficient in number to warrant a reopening of the controversy of guns and projectiles; but we cannot be too certain on such vital points in warfare as armament and ammunition, though to enter into a course of experiments heedlessly or unnecessarily, when every round from a 600-pounder costs the country about £9, would be wasteful. It is satisfactory to know on good authority that our service-guns are safe. Cases of

bursting are very few, and there are guns now in use which are in no way damaged after having fired 1,000 or 2,000 rounds. But with the knowledge which recent experience has given that the best gun is one of the safest steps to victory in warfare, we cannot afford to lose any opportunity of placing our naval ordnance in the highest state of efficiency. A step in this direction was taken last year by the issue of an order from the War Office for the construction of a 35-ton gun, which was completed a few weeks ago, and is to be simply an enlargement of the service gun; that is, it consists of a series of coils. We can form some idea of the gigantic size of this gun when we know that the outer coil consists of a bar of iron nearly equal in length to the height of the Monument. This enormous piece of ordnance weighs 35 tons 7 cwt., and will throw a 700 lbs. shot, which will pierce iron armor 15 in. in thickness; the ordinary charge of powder is calculated at 120 lbs. The tube of the gun, which is about 16 ft. long, was brought out of the factory in which it has been rifled and fixed, muzzle downwards, in a pit under a powerful crane; the heavy breech-piece—a mass of iron weighing 15 tons—was heated nearly to redness in order to expand the metal, and the heated mass was lifted and dropped like a cap over the breech of the perpendicular tube. The moderate calibre of the new gun is designed for penetrating, and the shot will probably be three times the length of its diameter. This monster cannon now only requires to be vented and proved to be ready for service, which it is confidently expected to be immediately. The estimated cost is £2,500. Sir William Armstrong's estimate for a 35-ton gun was £3,500, and Sir Joseph Whitworth's, £6,000.

One very important point was taken up last year in connection with naval ordnance, namely, the best way of protecting ships' decks, which are very vulnerable when exposed to danger from a plunging fire. Several experiments were conducted at Shoeburyness, which proved on the whole satisfactory to the navy, by showing that the penetrability of such decks as those of the Monarch and the larger ironclads was not so great as was imagined. Some interesting experiments took place at Liège in the course of the summer, the principal object of which was apparently to ascertain how to increase the durability of small guns, especially those of bronze. MM. Montefiori and Kunzel had invented some new process which was considered efficient; their idea being that by the mixture and addition of phosphorus, old bronze guns might be strengthened, and that with guns, as with men, phosphorus might be found to be the *vis vitæ*—the secret of lasting power.

A very successful and interesting series of experiments was conducted during the past year at Shoeburyness, in order to test the strength of Palliser shells with the heavy naval ordnance, and also the bronze field-gun for India. But the experiments which excited most interest were those with the mitrailleuse; since then the trials of real warfare in the last few months have determined the value of this arm. It is satisfactory to know, in regard to experiments, that the old-fashioned way of testing iron plates has been superseded; instead of using the old smooth-bore gun to test the plates of the Devastation and Glatton, last year, the 7-in. rifled gun was used with chilled shot.

We ought not to omit all notice of the torpedo experiments which have lately been conducted. Some reproach has been cast on the Government, not without reason, for having given too little attention to torpedoes; the subject has now, however, been taken up with vigor, and, after the melancholy accidents at Cuxhaven, will not be abandoned until our shores are protected against a hostile fleet by these formidable submarine engines of defence.

As regards the dockyards, the rapid progress made in the extension works at Portsmouth and Chatham require notice. When these works are complete, they will afford the most ample accommodation for our largest ships; but it will be some years hence. By means of an excellent plan devised by Colonel Clarke, C. B., the Director of Works, the marines have been employed on these works with the most successful results. At the commencement of the year, the reductions which so annoyed the Government and the dockyards, had been effected so as to bring down the establishments to their proper state of efficiency.

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One of the first things Mr. Childers did, was to reduce the staff of one of these

offices. So astonished were the members of the late Board at this, that they asked, on one occasion, how it happened that in a department which they had reluctantly been compelled to increase, the present Board was able, without any difficulty, to make its first reductions. The reply which Mr. Childers gave was convincing: "There was, indeed, a great necessity for writers' work at that office; but a great deal of the work was useless." In fact, it had been found that *by economizing the work it was possible to reduce the staff*, and that the efficiency of the work done was not in the least injured by the application of a little wholesome economy. After all, the whole secret of this and other anomalies which were found to underlay the traditional system of Admiralty work, can be found in the baneful practice of isolation. Isolation of men and work in Government offices is the secret of any want of success in their work, and of the ease with which mistakes are found by men, like Mr. Childers, who are sufficiently determined and energetic to remove them. Isolation has indeed been the bane of the Admiralty departments. In the case already referred to, this is palpable. Here were two branches of the same office, within a shilling cab fare of each other, and both, without knowing it, engaged on the same kind of work. Each of these branches was as completely isolated as though it belonged to some office in no way connected with the Admiralty, and each kept to its own traditions, and its own system of doing work, as though, instead of being only the part of a machine, it were the whole machine itself. But it is possible to carry this complaint further; indeed, it is barely an exaggeration to say that the same state of isolation existed between rooms under the same roof. The feeble and effeminate habit of writing little notes from one room to another can only be explained by supposing that there may be, in public offices, some notion that tenacity to a seat during office-hours is an official duty. Can it be wondered at, that under such a state of things, the business of the Admiralty, in its inner life, should have been obscured in a network of half intelligible correspondence, and that, in its intercourse with the outer world, this same network of correspondence should involve the most ordinary transaction; that personal communication should be avoided, and the practice of putting every trifle in "black and white" almost deified, and that, as a consequence, the most contradictory orders should be constantly given? To remedy these evils it was determined to bring the various branches of the office as closely together as possible under the eye of the Board, with the view of preventing the same work being done by two branches. But another evil had to be remedied, namely, the irresponsible position of the worker. For the highest, as for the lowest, class of work nobody seemed to be responsible. To such a height had this evil arisen, that every paper dealt with by a junior clerk, was so covered with initials before it reached its last stage, that it was difficult to say who could be held responsible for any error which might arise upon it. More than half the duties of each office consisted, indeed, in simply repeating processes which had already been done. To remedy this defect, it was determined to abolish a whole class of senior men whose duties had consisted of little else than checking work which had already been checked. The class below them was intrusted with the responsibilities of its own work, and received a slightly increased scale of pay; but the junior class was not materially affected by this alteration, beyond having a slight increase in responsibility for its work. To revert to the important subject of the navy. With respect to the number and strength of our war-ships, it is clear that a force of fifty iron-clads is not sufficiently strong. Mr. Cobden, the most peace-loving of economists, laid it down as an axiom that the British Fleet should be as strong as the navies of any two European Powers. But, without endorsing his dictum, there can be no doubt that we cannot discontinue ship-building, and that it is necessary to keep up our dock-yards both for building and for repairs of ships, and also to maintain a sufficient force of workmen to meet all the wants of the Service in this respect. Then, as regards officers, it is essential that we should have a staff sufficient, not merely for current requirements, but for emergencies; while, as regards seamen, it is no less necessary that the reserves should be ample and the men efficient. The Government has certainly not departed from its principles of efficiency,

nor, in straining after economy, has it sacrificed any of them. Ship-building is not discontinued; for, as has already been shown, Mr. Childers, acting upon professional advice, has adopted a certain rate which he is determined to keep up year by year; and, to provide for the repairs of ships, as well as for building, an ample supply of men is provided.

The most startling reductions have been made in the ranks of officers; but, upon investigation, it will be found that these reductions will increase, rather than lessen efficiency. And, with regard to the force of seamen necessary for the Service, it is satisfactory to know that it is both efficient and sufficient.

In fact, so far as reforms have yet been attempted, it is impossible to doubt that their tendency is to benefit rather than injure the Service; and to increase rather than lessen its efficiency. There have been errors; but how can they be altogether avoided in the execution of any reform? Such as have occurred are rather in matters of detail than principle, and no attempt has been made, or is even necessary, to conceal them or evade their admission. In the navy, the country wants a service complete and strong in all its parts; which shall be capable of affording protection to our commerce and our interests abroad, and of guarding our own coasts. The old idea, that mere numbers mean power; that large fleets, thousands of men, and acres of stores mean efficiency, has been proved to be erroneous. The Government, in boldly attacking this prejudice, has cleared the navy of what did not represent real strength, cut away masses of useless and cumbrous top-hamper, and at the same time introduced an economy which has already materially lessened the burden of taxation.

The following list of our fleet of iron-clads must carry the conviction to all unprejudiced and impartial minds, that we are able to cope with any naval force that can be brought against us:

BROADSIDE IRON-CLADS (36 IN NUMBER).

1. Hercules, Sultan.
2. Audacious, Invincible, Vanguard, Iron Duke, Swiftsure, Triumph.
3. Bellerophon, Lord Clyde, Lord Warden, Minotaur, Agincourt, Northumberland, Royal Alfred, Penelope, Repulse.
4. Achilles, Royal Oak, Prince Consort, Caledonia, Ocean, Valiant, Hector, Zealous.
5. Warrior, Black Prince, Defence, Resistance.
6. Pallas, Favorite.
7. Enterprise, Research, Viper, Vixen, Waterwitch.

Added in 1870: None.

TURRET IRON-CLADS (15 IN NUMBER).

1. Devastation, Thunderer.
2. Monarch.
3. Glatton.
4. Hotspur, Rupert.
5. Royal Sovereign, Prince Albert.
6. Wyvern, Scorpion. Added in 1870.

At the dockyards: Fury, Hecate.

By contract: Cyclops, Gorgon, Hydra.

Not only in ships, however, but in officers, seamen, and guns, is the navy in a better state, at the opening of the year 1871, than it has been for years.

THE HOOSAC TUNNEL.—This wonderful bore of 5 miles through the Hoosac Mountains, goes forward with persistent steadiness, and bids fair to be an accomplished fact in 1874, as promised by the contractors, the Messrs. Shanly. Some conception of the magnitude of this great work may be formed when it is known that at the west end the workmen have fully one-third of a mile of solid mountain above their heads.

INTERCOLONIAL RAILWAY.—All the sections of this important undertaking have now been let, and it appears by an official report which has been issued, that altogether about 8,000 laborers are employed upon the work. Every effort is being made to carry on the line economically.

THE Brooklyn tower of the East River Bridge is fairly commenced on its permanent foundation. It is to be built of granite from Maine.

The caisson for the New York shore is about complete, but will not be launched probably till about the 1st of April.

A NEW depot is being built at Woodside by the Paterson and Newark Railroad Company.

CHROME STEEL.

The "Iron Age" says of the Chrome Steel Company and their works, in Brooklyn:

The Company claim that they have introduced the only great improvement in crucible steel made in many years, since by their process a perfect uniformity, a perfect homogeneousness, is insured as an absolutely certain result of their manner of working, as applied to the several grades of steel they manufacture, and especially to their high grade tool steel. They are quite certain that they can make a better steel out of a poor quality of iron than can be done by any other process; but they do use only the best kinds of steel-making iron in their manufacture. Well, in this essential, as well as in carefulness of working, they cannot claim superiority over many other steel makers, but they do show wisdom, *prima facie*, in recognizing the principle that good iron is the foundation for good steel, especially since they keep a portion of their process to themselves, and thus are exposed to attack from all other makers, as well as from the scientific fraternity. They use American iron for some kinds of steel, and, in fact, they refine some of the foreign iron before using it, while refining the steel is a part of their process, the details of which, however, they keep secret.

We saw the Norway bars cut up and charged into the crucibles, into which the powdered preparation of chrome is also introduced, they say, to the extent of 5 per cent. This chrome ore is mined near Baltimore, and contains protoxide of iron, magnesia, alumina, no silica, and, when pure, 60 per cent. of oxide of chromium. The crucibles are closed with covers and put into the melting furnaces, of which there are two, an 8-pot ordinary furnace, and a 24-pot Siemens gas furnace, which latter is a very substantially built and successfully working structure. In this the Mount Savage fire-bricks have been used, and give all satisfaction. The gas is made on double grates in a furnace situate under a separate shed in the rear of the works. The fuel used is the best Cumberland coal (Scranton), for although in these generators the poorest kind of fuel can be employed for making the gas —even sawdust, if nothing else were to be had—it has been found that the best is the cheapest. The Siemens furnace shows an economy of 50 per cent. in fuel over the old style of melting furnace in these works. The gas is led under ground into the fire-brick regenerating chambers of the furnace proper, situated to the right and left of the combustion chambers, into which the pots are set, and underneath which the furnace is open to avoid trouble in case of removal of pots, and to give access for repairs. Having valves outside of the heated portion regulate the flow of gas and air. Sturtevant blowers making 2,200 revolutions per minute, noiselessly, are used for furnishing blast to the reheating furnaces. The crucible room is covered by sectional brick arches held by clamps, and in it, by the combustion of the gas and air, an intense white heat (blue) is created, which soon melts the metal and effects the "reduction," as it is termed here. Meanwhile, the iron ingot moulds have been placed in upright position near the furnace, but below the working floor, so that their top comes about on a level with it. The workmen stand ready with bars to lift off *seriatim* the sections of the arch. One seizes and lifts out a crucible with the tongs; another knocks off the cover and skims the top of the metal with a tool which looks more like a drum-major's stick than like a dipper, while a third proceeds to the operation of refining, or whatever the operation ought to be termed, for its nature is kept secret. All one can see is that some powdered substance is carefully weighed and poured out of a cup fastened to a handle upon the top of the metal and stirred in, producing a trifling combustion and some spluttering of fiery shooting stars, with increase of light from the metal in the crucible, whereupon the contents of the pot, liquid as water, are emptied into the mould, and the crucible rolled away to cool. But all these operations do not occupy more than it takes to describe them. The crucibles used here are made in the Jersey City Crucible Works, and last three heats. Being made of graphite, the probable absorption of carbon in the metal has been recognized and carefully considered by the chemist.

The ingot very quickly sets. We eagerly examined its surface, and found that it was perfectly regular, compact, smooth, solid, without seams, or pipes, or flaw; no sinking in, or roughness, or imperfect metal to be seen on top.

When convenient, the ingots are taken hot under the hammer, and there hammered into shapes to suit further manipulations, the metal behaving as kindly as cheese, losing, however, a scale of 1 13-100 per cent., which is thrown away. The workmen say that they have not lost an ingot since the commencement. When required, the ingots or bars are reheated upon large open coke bars, served with a blast from underneath. The Company have six of Davy's direct-acting steam hammers in operation and one erecting, which work to a charm. The foundation of the anvils is well constructed, so that no shock or shaking occurs. Such blocks as are intended for slicing and rolling are reheated and rolled under chilled iron rolls into bars or rods of the usual shapes, which, if necessary, are cut into the required lengths and properly labelled for the consumer, the grades of steel having been kept altogether separate from the beginning. Other ingots are cast for forging into shapes, according to orders or patterns received from consumers. We saw fine workmanship in some cutter-heads destined to make 2,000 revolutions per minute in a large planing machine for an Eastern factory, the main portion being triangular in profile, with round smooth axle ends.

The expenditure of fuel is about 3 tons of coal to 1 ton of steel. The present capacity of production is about 1,500 tons per annum; it is contemplated, however, to erect a Martin furnace beside the crucible furnaces, which, with the additional train of rolls, would give a much larger capacity.

The Company hold that their steel is superior to anything manufactured in this country or in Europe, and back up their assertion by their willingness to prove it under any forfeiture—but, what is more to the purpose, they guarantee every pound they sell. They say that it has properties and advantages entirely its own, and is especially adapted for tools of all kinds. It can be worked at a white heat—and "cannot be injured by over heating." It can be welded to iron or to itself, leaving no trace of the weld; it can be worked and reworked without injury; and, they claim that, when made into a tool, it will do at least 50 per cent. more work than any steel, not excepting the highest priced, and be perfectly uniform in each grade, and they so warrant it, with this qualification, that it must be treated according to directions, which are mainly that it should be dipped at a low red heat, as seen in the shade; that all tools forged from a large body to a small edge should be allowed to cool off after forging, and be reheated for tempering, and they claim that the only way in which it can be spoiled is by dipping it in water or hardening mixtures when too hot. Several bars were heated to almost a white heat at our request, then worked, reheated and reworked, tempered, and a specimen cut off, of most beautiful fine grain, so hard as to cut glass, which, by the by, we showed to a well-known steel maker of Jersey City afterward, who said that if it were English steel it would not be worth anything, would be brittle as glass, but if chrome steel, it would make a tool that would "turn the hardest chilled iron roll," a compliment from a competitor. Another of the bars thus put through the white heat was split, allowed to cool, then heated again, hammered together without flux, and a chisel forged out of it, the edge being on the weld, which was tempered at very low heat, ground, and then tried on an ingot of steel, cutting out chips to half an inch deep, without showing any mark of bluntness or fracture; we took that cold chisel home as a sample. It shows the mark of having been sliced half way up the handle. As a test of toughness we were shown a $\frac{5}{8}$ in. square bar twisted cold until it looked like a cable, also a turning-lathe shaving 40 to 50 ft. long. Dynamic tests of this steel have been made by David Kirkaldy, in London, also at West Point Foundry, which latter showed as the highest strength of 12 specimens, 198,910 lbs.; lowest strength of 12 specimens, 163,760 lbs.; average of all the specimens, 179,980 lbs.; or say, 180,000 lbs. per square inch, which is $\frac{1}{9}$ more than Percy gives as the highest tensile strength attained in steel.

It is further stated that run into wire it will tie into knots, and stand 400 lbs. more in No. 16 than the wire used by hoop skirt makers; and Mr. Wood says that he

can make a tool from it to drill through Stubbs' hardest file. The tools made from this steel have been tested by Government engineers—for instance, upon the rocks at Hurl Gate—who have given very flattering certificates of its working; and from various parts of the country manufacturers have sent testimonials of its superiority for various purposes; but the most curious indirect compliment was paid it by parties who were recognized as illegitimate drillers, and, therefore, did not obtain what they wanted, *i. e.*, tools to work through a chrome iron safe.

RELATIONS OF TRAINS TO CURVES.

By S. J. WALLACE.

From "The Railroad Gazette."

Curves are requisite elements of railways, and they involve the provision of certain elements in trains. These are: Provision for keeping on the line of track, as flanges on the wheels; provision for bending the train around curves, as forming it in jointed sections; provision between the sections for the draft; and provision between the sections for resistance, as bumpers.

Draft is an element which must be extended throughout the train, reach in a vertical line from the locomotive, and must have strength equal to the strains.

The frame-work of the separate sections, or cars, may be made to serve as parts of the line of draft through the train; special parts may be provided for the purpose, and arranged in jointed parts, to which each car may be secured, leaving the car frames free from the strain.

The line of draft, whatever be its construction, should pass in a direct line from the locomotive through the train. It may pass through any portion of the cross section of the cars. But if it is not virtually in the centre line of resistance—that is, with all its joints and weak points in that line—then a strain will be thrown on one side and cause the flanges of its wheels to act against the rail with a resistance to balance the two sides. This will cause loss of power, besides the wear and tear.

On curves a simple direct line of draft cannot pass through the train. A consequent loss of power would occur on the inside rail by the strain of the engine to straighten the train, but for the composition of forces. The impetus tends to throw the train against the outside rail, in the effort to pursue a straight course. In such case, if the engine exert no new power the train will lose force against the outer rails; and if the train were stopped on the curve, the engine, in starting, would have resistance from the inner rail. On all curves this composition of the two forces takes place. If the speed of train and the exertion of engine are in right proportions to each other and the curve, the curvature of the course becomes a natural result of the united forces, without loss of power. But if the engine exert too much effort on a curve when the speed is too low, the tendency is to drag on the inner rail and to turn a short curve; and if the speed be too high with the engine too slack, the tendency is to drag the outer rail and to turn a large curve; while, if either rail drag, there is a loss of motive power.

The line of draft should be in the vertical plane of the centre of resistance in the train, on straight lines. On curves the height of the line of draft is important. If it was several feet high, too great a strain toward straightening the train on a curve might turn the cars over to the inside of the curve. But if it were in line between the two rails it would be impossible, because the rail would lie in its direct line of strain. Thus the lower the line of draft can be placed in the train, the more secure it is. This is also nearer the true line of resistance.

In passing curves with speed, heavily loaded cars will be thrown against the outer rail with force, while empty ones may be drawn against the inner rail by the force of the draft.

When the force of the engine is exerted on curves, the tendency is to throw the pair of wheels at each end of the train against the outer rail, and to draw those in the body of the train to the inner rail.

The requisite provision between the

sections of a train to resist the impact of mass motion between the cars should be at, or as near as may be to, the centre of the weight of the cars, and should act upon the main frame of the car sufficiently to communicate requisite impulse to the weight. But it is a question whether it might not be better to use a special part to communicate the action through the train, and thus free the car frame from all the strain and shock except the separate shares of each. On curves the action of such bumpers is better to be arranged to act at or toward the inner side of the train.

Car wheels have been made with conical treads to assist them in passing curves without slipping. But as it is very uncertain which rail they will be forced against, this becomes an evil, because the wear and tear of wheel and rail is increased by the greater amount of slip required when the large part of the cone is thrown on the inside rail. Besides, level tread wheels have been found to avoid the excessive rocking motion of trains, resulting from the alternate action of the cones on each side.

This partial review of the relations of trains to curves is intended merely to assist practical men to master the running of their trains, to assist engineers of construction, railway companies and inventors, in understanding the forces they have to do with, and to assist science in grasping great problems.

AN ACCOUNT OF THE REMOVAL OF SOME BROKEN PILES FROM THE BED OF THE CONNECTICUT RIVER.*

During the winter of 1868-9, the clusters of piles driven for the "Cushing Piers" of the Connecticut River Bridge, at the Shore Line Railroad crossing, were left exposed and unprotected on account of the serving of an injunction, which prevented the continuance of the work.

The up-stream cluster of Pier No. 2 had but four piles driven when the work was suspended. These stood in 37 ft. of water at low tide.

The freshet of the following spring brought down the river immense fields of thick ice, which formed a jam just above the site of the bridge.

When this gave away, it tore the platform from its place, carried away two of the four piles and broke off the other two. One was broken off just below the surface of the river bed, and the other about 2 ft. below the first. When the work was resumed in the summer of 1869, it was found necessary to remove these stumps or to change the location of the pier.

As the work on the superstructure was well advanced, it was determined to remove them.

Various methods were tried with poor success. The bed of the river is composed of a fine sand, which flowed back around the pile-heads as fast as a diver could remove it.

A curb of iron, 8 ft. in diameter, and 3 ft. high, made of three-eighth inch boiler plate, was sent down for the diver to settle around the piles, so that the heads could be cleared and a chain be passed around them, but progress was so slow, that method was abandoned and the following adopted, which proved perfectly successful.

A 4-in. gas-pipe, 5 ft. long, with a solid steel point, was placed beside the heads of the piles by the diver. Into this was inserted one end of an iron rod, long enough to reach from the bottom of the river to the reconstructed platform. On this rod was shrunk a heavy iron ring, just above the top of the gas-pipe, forming a shoulder for a hammer, sliding upon the rod, to strike upon.

By means of the hammer, which was raised by the pile-driver engine, the pipe was driven down until its top was within 2 or 3 in. of the surface of the river bed. When the tube was in place the rod was withdrawn and a charge of 4 lbs. of powder, enclosed in a tin cylinder, inserted, which was covered with the river sand and exploded by means of a battery.

Both piles were thrown out by the explosion. One was uninjured; the other was broken at about a right angle with the grain of the wood, the break extending to within about half an inch of one side.

The fracture was a perfectly clean one, none of the fibres of the wood pulling

* A Paper read before the American Society of Civil Engineers, by J. Albert Monroe, C. E., Member of the Society.

from one part to the other, and it was as clean as if the wood had been partially decayed.

These sticks were of yellow pine, 12 in. square and 12 ft. long, and were driven the November preceding.

ACCOUNT OF FLOATING DOCKS, MORE ESPECIALLY OF THOSE AT CARTAGENA AND AT FERROL.

By Mr. GEORGE BANKS RENNIE, M. Inst. C. E.

From "The Artizan."

After touching upon the various modes formerly adopted of cleaning and repairing the bottoms of ships, the author referred more particularly to the wooden floating docks introduced by Mr. Gilbert, in the United States of America, and to that made by him, in 1858, at Venice, for the Austrian Naval Arsenal of Pola, in which the two largest ships that had been docked, were the Kaiser, of 3,225 tons, and the Ferdinand Max, iron-clad, of 3,066 tons. The Messrs. Rennie, having been called upon by the Spanish Government, to make a proposition for furnishing a Floating Dock for Cartagena, capable of raising the class of iron-clad ships then about to be added to the Spanish Navy, having a weight of from 5,000 to 6,000 tons, which represented the "Numancia" and the "Vittoria" types, they proposed a dock somewhat similar to that constructed at Venice, but of iron instead of wood, with certain important modifications. In the wooden structure, in order to sink the dock sufficiently, it was not only necessary to allow water to run into the lower chambers, but water had to be forced into the top compartments at the sides, to overcome the buoyancy of the material; while in the iron structure provision had to be made to prevent the dock sinking when the lower chambers were filled with water. To accomplish this, the upper part of the side walls was divided into compartments, forming permanent air-chambers, or floats, of a capacity sufficient to maintain the decks of the side walls from 6 to 8 ft. above the water level. The author laid stress on the importance of these for the safety of iron floating docks. As an instance of the success of the Cartagena Dock, he mentioned that the Numancia, of 5,600 tons weight, had been supported on it for a period of 80 days. A list was then given of wood and iron floating docks which had come under the author's notice, all of which were of rectangular shaped sections, with the exception of the Bermuda, which was of a U section. This latter form required gates or caissons to close in the ends, which were not necessary in the rectangular section, on account of the bottom and the keel of the ship being entirely raised out of the water. Less water had also to be discharged with the rectangular form, and the amount of pumping varied as the weight of the ship, whilst in the other or U form, the smaller the ship the larger the volume of water to be discharged. The depth of the basement or lifting chamber of a floating dock, like that at Cartagena, mainly depended on the lifting power required. The thickness of the plates of the shell was $\frac{5}{8}$ in. and $1\frac{1}{4}$ in. in the centre part. For such a vessel as the Numancia, weighing 5,600 tons, the strain was estimated to be 1.32 ton per square inch, and for a vessel weighing 20 tons per lineal foot 1.5 ton per square inch.

Of the different plans of conveying docks to their destination, it was remarked that that of Pola was built at and towed from Venice, that of Havana from New Orleans, that of Alexandria from France, and the Bermuda from the Thames; while those of Cartagena, Ferrol, etc., were sent out in pieces and erected at the respective ports.

The necessary repairs, painting, or cleaning, might be performed by careening, beaching where there was sufficient rise and fall of tide, raising the submerged part out of water by pontoons, or by floating the dock into a shallow basin; this latter plan being the one adopted at Cartagena. The dock at Cartagena was 324 ft. in length, 105 ft. in breadth, and 48 ft. in height outside; these dimensions of the dock at Ferrol were 350 ft., 105 ft., and 50 ft., respectively. After giving a detailed account of the number of chambers into which the docks were divided, and the scantlings of the materials em-

ployed in their construction, the pumping machinery was described, and it was stated that it had been designed so as to be as much concentrated as possible, and thus be capable of being placed under the control of one man. The arrangement adopted was that of a pair of horizontal engines, working two pairs of lift pumps, to draw water from a common pipe, communicating with all the chambers. On the ends of these pipes were fixed the inlet sluices for filling the chambers, and on the sides smaller sluices and pipes in communication with each chamber, so that by opening all the sluices the chambers were filled, and on shutting the inlet sluices, one or any number of chambers might be discharged. Thus the whole engine power might be employed in pumping out any one compartment if it was found desirable to do so, in order to balance or level the deck. A detailed description of the engines, pumps, and sluices was then given. The shallow basin, or dock receiver, with its three lines of ways or slips, occupied the site of some old timber ponds. The basin was of a uniform depth of 16 ft. 6 in. from the top of the quay wall, and the depth of water was 12 ft. 3 in. The entrance was 126 ft. wide. The basin was 382 ft. long on the north side, and 345 ft. on the south side. The end was curved, the chord of which was 200 ft. From this end ran three lines of horizontal ways or slips, radiating to a centre. Each was 725 ft. long and 45 ft. broad, and each was laid with four lines of timber ways, intended to receive vessels after they had been raised by the floating dock. It was estimated that six vessels might be building or be under repair at the same time, besides one on the floating dock. The foundations and masonry work were then described, and it was mentioned that the caisson for closing the entrance of the basin was similar to that made by the Messrs. Rennie, for Pola. After the basin and dock were completed, water was let into the receiving basin, when the draught of water of the dock was found to be 4 ft. 7 in., giving a displacement of 4,400 tons as the weight of the dock complete. The dock was afterwards taken into the arsenal basin, and lifted vessels of various sizes—the iron-clad, Numancia being the largest. The draught of water of the dock with the Numancia was found to be 11 ft. 3 in., the dimensions of the ship being, length between the perpendiculars 316 ft., extreme beam 57 ft., and displacement at the load draught 7,420 tons. The operation in docking this and other vessels had proved the dock to be in every way efficient, and from the arrangement of the distributing valves, it could be managed with facility, either in sinking or in lifting. The *personnel* of the dock consisted of one chief engineer, one master boiler-maker, and with other assistants, amounted to eighteen men in all, and with this staff everything went on regularly and without trouble.

AMERICAN LOCOMOTIVES.*

By Mr. A. BRUNNER.

The American railroad engine, as compared with European locomotives, bears upon its face the stamp of much fertile originality, similar to that of American steamboats and bridges, when confronted with transatlantic works of a kindred class. There are differences, in the construction and working of American means of land-and-water intercourse, which may be called only *external* ones, arising from the peculiar tastes and manners of the people; but, between American engineering practice and that of the old country, there are also *principal* distinctions, called for, often, by strictly limited expenditure, by the necessity of speedy completion, and dictated in many cases by Nature herself.

It is on the American continent, where some of the grandest wonders of the world, of nature, and of art, simultaneously appear before the traveller—whether he be traversing endless prairies and the Sierra Nevada on the Pacific railroad, or skirting on a "floating palace" along the beautiful scenery of the American Rhine, the Hudson river. And probably there is no other place on the whole globe where such an impression of might and majesty is left upon the mind—no other

* This letter was originally prepared for a leading English scientific journal by a European engineer of wide experience among railroads.

spot where such a sublime scene of Eternal power and of mortal effort bursts upon the view, as at the Falls of Niagara and the Suspension bridges. It was a bold idea to stretch such a wonderful structure, as was completed by Mr. Roebling, across Niagara river, which signifies, in the symbolical language of the Iroquois Indians, "*Thunder of Waters*," streaming deep below the table land through its rocky bed, and boiling and leaping and foaming onward to the whirlpool ;—and there is also the new and graceful, 'though less monumental, Clifton bridge, suspended like iron cobweb over that tremendous ghost of spray and mist, that perpetually arises from the bright-green water in its giant leap!

Such challenges, and many other difficulties, the American engineer has met with an initiative, an amount of pluck and mechanical instinct which—as must be universally admitted—do him much individual credit, and honors the whole nation. But to return to our subject, viz.: "American locomotives." I have examined them in detail at the manufactory; witnessed their performances on all kinds of track, and I am compelled to confess, that what I saw far exceeded my anticipations.

Beginning with the engine and the various mechanical details, as designed and constructed in the manufactory, a very marked difference, as compared with English practice, will be noticed. The boiler is invariably lighter, the maximum thickness of the iron plates composing the barrel and fire-box being $\frac{3}{8}$ in. (with the exception of the tube plates, $\frac{5}{8}$ in. thick), while steel plates from $\frac{1}{4}$ in. to $\frac{5}{16}$ in. are frequently used. The boiler tubes are generally of iron. The longitudinal seams of the boiler and fire-box casing are double riveted, and they are, moreover, strengthened, in many cases, by flat bars of iron, placed sometimes across the joint at short intervals, sometimes right along the joint on the inside of the boiler. The fire-box crowns are usually stayed by transverse stays, composed of two plates $\frac{5}{8}$ in. thick, which are welded together at the ends ; these stays being connected to the crown of the fire-box casing by sling links. The fire-box casing is generally raised above the boiler barrel, the junction between the two is effected in a simple manner by the "connection sheets," forming a short conic barrel, and dispensing thus with the tedious operation of moulding the front casing plate to any intricated shape. No solid wrought-iron rings are interposed at the fire-door and fire-box bottom, but the plates are flanched so as to meet, when they are riveted together. The smoke-box is usually cylindrical, forming a continuation of the boiler barrel, and resting on a cast-iron saddle, which carries in its turn the cylinders, and, in some cases, also the bogie pin.

One of the peculiarities in American locomotive construction is the framing, which is made of square bar iron, welded together, slotted, planed all over, and entirely finished. The "bar frames," besides being very rigid in every direction, admit of easy access to the link motion; they form at the same time a good base for attaching the various brackets and guide-plates. The cylinders, which are usually outside, are hung from the top bars of the frames, in order to insure a firm base for the cylinders, and to prevent independent strains on the frames, a cast-iron separate bed-plate or "saddle" is inserted between them, or the cylinder castings are made to extend inwards, where they are firmly bolted together. The valve-chests are on the top of the cylinders—a very good plan, by the by—the valves receiving their reciprocal motion, through the intervention of rocking shafts, from the eccentrics and motion links, which are placed, as in English engines inside the frames.

As a rule, the various details of the motion and gearing are admirably well proportioned and carried out, although, for the sake of cheapness, "professional etiquette" is sometimes grossly neglected, as witness cast-iron piston-rod crossheads, cast in one piece with the pin and guide-blocks! The ends of the connecting and coupling-rods, where they take hold of the crank-pins, are always fitted with straps, secured similarly to the large ends of connecting-rods for inside cylinder engines. The brasses are generally closed on the outside, so that the crank-pins may be entirely enveloped, and by this "dodge" (which is well worthy of imitation) the pins are kept out of the way of dirt. An attempt is often made to guide the piston-rod crossheads by bars, arranged *above* the centre-line of the cylinders. Sometimes a single guide-bar only is employed, care being taken, however, to give it the necessary rigidity, and to pro-

vide ample bearing surfaces for the upward thrust and the downward pull of the connecting-rod. The object of this arrangement, which is identical with the plans of Mr. Stroudley and of Mr. Reynolds, is to clear the bogie wheels, or to effect, in the case of an engine with the leading wheels coupled, a reduction of the distance at which the cylinders are apart transversely.

The cast-iron wheels form another distinctive feature in American practice. The small chilled cast-iron disc wheels of their engine-tender and car trucks answer admirably well, being cheap, strong, and durable at the same time; but, as regards the driving wheels with hollow spokes and rim, they are, after all, but a primitive contrivance as compared with the solid wrought-iron wheels now manufactured to such perfection by the leading British locomotive makers, and especially by some Belgian and French firms. To turn out a really good wrought-iron wheel, special tools and appliances, and superior manual skill, are indispensable, and it is, perhaps, the lack of these that has prevented the Americans from making an attempt in this direction.

The boiler feed-pumps also deserve mention, injectors being totally ignored, or, if employed at all, of such dimensions as to serve merely as auxiliary boiler-feeders. The pumps are always placed on the outside of the frames, and frequently even outside the coupling-rods, in which latter case they are bolted on the guide-bar brackets, being thus of very easy access. The pumps are usually worked from the piston-rod crossheads, and they are provided with 2 air-chambers, 1 for the suction and 1 for the delivery-pipe.

Much ingenuity is displayed in the manner of setting engine and tender on the wheels; in fact, the problem of making an easy riding engine, offering, at the same time, the least amount of internal resistance, has been solved by the Americans most successfully. Much might be written on the history of the swivelling-truck, the faithful "track-feeler" of the American locomotive, and it would take a very graphic pen, indeed, to record fully all the modifications and transformations this useful contrivance has already encountered. Swivelling-trucks — better known, perhaps, by the quasi-mysterious name of "Bogies"—are employed as carriers under the engines, tenders, and cars on all American railways, but, as far as I could learn, no attempt has ever been made to utilize the advantages of the bogie system in that part of the engine, which, properly speaking, supplies the traction power; in other words, the steam-cylinders and gearings are always fitted to the main system of the engine, independently of the bogies. If the trucks, as they roll along, are watched from the car-platforms, it will be noticed that they get the more uneasy the more the speed increases, manifesting, at high speeds, a strong, "galloping" movement; and this characteristic phenomenon would, perhaps, be seriouly aggravated by the additional disturbing forces resulting from the employment of steam-cylinders. At all events, the check-chains provided throughout, in connection with the American trucks, are not suggestive of abundant safety. For heavy work, at very low speeds, however, such as climbing crooked inclines, it would be advisable to employ engines mounted upon 2 steam-trucks, whereby both the power and the flexibility of the locomotive would be increased. Compensating levers are used on all American engines, not only between the coupled driving-wheels, but often, also, between the front pair of coupled wheels and the bogie. In many cases the equalization of the weight is still further carried out by the employment of transverse compensating beams, as used also by Borsig, and on almost all the German locomotives.

As regards the general form of American locomotives, the most striking feature is the extent to which the weight is subdivided over a greater number of wheels. The standard passenger engine has invariably 4 coupled driving wheels, 1 four-wheeled truck under the forward part of the locomotive, and 2 four-wheeled trucks under the tender, making in all 16 wheels against the 10 or 11 wheels of an English engine of similar proportions. On some lines, the goods traffic is worked by exactly the same type of engine, the increased traction power being obtained merely by a slightly reduced diameter of the driving wheels, and a few tons more adhesion. But, what may be termed the "standard" goods engine, has generally 6 coupled driving wheels of from 4 ft. 3 in. to 4 ft. 8 in. in diameter, while the driving wheels

of the passenger engine range from 5 ft. to 5 ft. 8 in. in diameter. The weight of the passenger locomotives, loaded, is from 27 to 30 tons, of which weight 60 to 65 per cent. rests on the coupled wheels. The weight per driving wheel on the goods engine is very seldom more, but having usually 2 coupled wheels more, the adhesive power of the goods engine would consequently be 50 per cent. greater than that of the passenger engine.

In outside appearance and finish the American locomotives present much original conception and, not unfrequently, real artistic merit. The Yankees seem to place great pride in their engines; and it is indeed a proud sight to see an American engine entering a station, blazing in polished brass, embellished with rich peinture, bells ringing and whistle roaring—a sight very apt to compensate, temporary for the noted shortcomings of American stations. At a first glance, some of the accessories, that give so much individuality to the engine, as cow-catchers, signal bells, tremendous head-lights and mighty steam-whistles, may appear somewhat superfluous; but this idea is soon dispelled when a journey is made on the engine foot-plate. It will then be observed that there is nobody to keep the track; at way crossings there is no barrier of any kind, but a board is stuck up instead, bearing one of the following warning descriptions : Railway crossing! Look out for the engine! or, as here in Lower Canada : Traversée de chemin de fer! The well-known voluminous smoke-stacks are necessary on account of some kinds of fuel consumed, while the commodious "cabs" shelter the men, through summer and winter, in the performance of their arduous duties. We will now proceed to witness the performance of American engines. One of the most striking observations is the ease, not to say "grace," with which the comparatively light locomotives do their work—and heavy work, too—over the rough roads of the United States and Canada. Mr. Eugène Flachat is evidently of opinion that the engines are worked at the sacrifice of regularity, speed, and security, for, on page 229 in his "Traversée des Alpes," he says :—

"The American locomotives are not constructed on a system that gives them a superior power to that of other engines; they are used on the inclines to the maximum of their power and adhesion. This produces an irregularity in their running which would not be admissible with the great number of trains on our lines, nor with safety, which is the matter of first importance in this mode of travelling. The American engine and train is to be compared to a ship crossing the ocean. She sails fast when everything is favorable; she goes slowly when the work is increased by the variation of the profile; she overcomes great inclines by reducing her speed considerably, without the machine being endowed with any superiority as to the production of steam, or to the means of transmitting the motive power of the cylinders to the wheels."

The average gross tonnage of passenger trains here is probably double that of English trains; still, with from 6 to 7 passenger cars, weighing, loaded, about 20 tons each, a baggage-car of the same weight, and a Pullman drawing-room or sleeping-car of from 30 to 35 tons weight, the engine gets quickly away from the stations, and without "slipping." Of course there must be some material reason to account for the superior useful effect given by American engines. In the first place, American engineers generally take the car friction at 5 lbs., and the engine friction at 10 lbs. per ton, irrespective of atmospheric resistances. These low figures—accepted, probably, more by long experience than by any direct experiments upon train resistances—must be attributed chiefly to the employment of bogie rolling-stock, central buffers with loose couplings and oil-tight axle-boxes, which latter are always lined with an excellent bearing alloy. I have had some conversation, on the subject of locomotive performances, with one of the leading railway engineers in the States, and although the theories then advanced may not universally be accepted as infallible, yet they carry such weight with them that it will be well to enumerate them here. These points, which are independent of train resistances, refer essentially to the great steaming power of American locomotive boilers, and to the manner in which these boilers are being worked and fed. The quick steam-generation is mainly due to three causes, viz.: the intensity of the fire, the thinness of the plates composing the fire-box, and the extremely forced draught.

By these means a boiler of moderate proportions and heating surface is worked up—though at a more rapid rate of combustion—to an extent never attempted abroad. The injector has been condemned by the Americans as being an expensive boiler-feeder. Counter pressure steam-brakes are equally unpopular out here, but each swivelling truck under the train, with the exception of the leading engine bogie, is always furnished with a hand-brake.

Great activity prevails in American railway matters, and all the locomotive works are consequently very busy. I understand that Messrs. Baldwin, of Philadelphia, will have turned out not less than 200 locomotives during the last 12 months. Locomotive building on this continent must, indeed, have made great progress of late, as verified by the perfect organization of the workshops and the systematical manner in which the work is turned out. In general, my visit to this great country has made a lively impression on me, which, I am sure, will be shared by most impartial critics, that in the specialty of locomotive construction the Americans are fully equal, if not ahead of the best European practice.

SEWAGE CROPS.

From "The Engineer."

Every candid and impartial person will admit that the question of the utilization of sewage upon the principle of irrigation has successfully passed through the preliminary stages. The first steps, so difficult to achieve, have been gained. The advocates of this system, which we were the first to uphold and maintain, have, after a hard fight, discomfited their enemies, vanquished the violent opposition they experienced for so long a time, and established the truth and soundness of the principle to the satisfaction of the Government, of local boards, and of private individuals. There are still, undoubtedly, a few who refuse to believe in the facts placed before them, and, with that invincible obstinacy which some of the human race possess in common with the lower animals, deny the accuracy and impeach the veracity of results that carry the fullest conviction to the minds of the dispassionate and disinterested. As the present year will probably prove an eventful one for the sewage problem, let us briefly review the claims it has to the consideration of the sanitary engineer, and those authorities whose especial duty it is to provide for the removal and disposal of the sewage of our towns and villages. It has been demonstrated that sewage can be applied with profit, agriculturally and financially, to nearly every description of plant and crop that is grown in our climate for the use and convenience of man. Respecting the kind of crop upon which it can be utilized most effectively, we shall have a word to say hereafter. One of the principal points to establish in a conclusive manner was, that this beneficial result could be obtained without creating a nuisance. Many who acknowledged the value of sewage as a fertilizing medium, were yet of opinion that its utilization in practice would be attended with so much annoyance to the neighborhood, as to give rise to legal proceedings which wouldt erminate in the granting of an injunction against the prosecution of the undertaking. In a very few instances, notably near Kingston, and at Bromley, Kent, the opposition of landed proprietors was sufficient to stop the measures that ought to have been carried out for the welfare of the inhabitants. But the evidence of several years' residence by laborers and their families on sewage farms, and in their immediate vicinity, is a proof that there is nothing in connection with works of this description injurious to health. The mere presence, during extremely hot weather, of any slight effluvia from the carriers or channels which distribute the liquid over the farm is of little or no moment. An odorless manure is of very little value, as every farmer will assert. We have walked over numerous sewage farms, and never experienced anything approaching the smell that proceeds from fields newly manured with ordinary farm-yard manure. There is nothing more intolerable at certain seasons of the year than the smell of flax-fields, but we never heard of its being productive of any ill-effects upon

the people dwelling near. Although in a sanitary point of view there may be no evil to be anticipated from the proximity of a sewage-farm to a populated district, yet the recommendation is no doubt a wise one which advises that land appropriated to the purpose of the utilization of sewage by irrigation, should not be situated at a less distance than one mile from a town.

Besides the utilization of sewage as a fertilizer for the land, there is another feature belonging to the problem which is equally, if not more, important. It is the disinfecting and deodorization of the sewage. After extracting the valuable manurial ingredients from the highly diluted fluid mass, there remains a very large quantity of liquid which is of no further use. Nevertheless it is necessary that it be disposed of in some way or another, and the readiest means of getting rid of it was simply to allow it to flow into the nearest natural wtercourse. This was the very plan that was first adopted in disposing of the raw sewage, and one which the whole system of irrigation is intended to prevent. Nevetheless, if the effluent water, as it it termed, or the liquid remaining after the utilization of the sewage had been accomplished, could be purified to a sufficient degree, it might then be permitted to be discharged into the adjoining river or stream. It became, therefore, incumbent upon the advocates of the irrigation principle to demonstrate that, after passing over the land, the effluent water was free from all offensive and deleterious particles, and might be turned into a stream without polluting its contents. This point was in truth more essential than the other, for as injunctions were granted against local boards and other offending parties for fouling rivers and streams, the first step was to avoid this in future. It must be borne in mind that there was not, nor is not, any obligation, legal or otherwise, to utilize sewage in any manner whatever. The obligation is to keep it from polluting the natural watercourses of the country, and irrigation, or any other mode of treatment, is only a means to the end. As the course of action local boards and sewer authorities have recently found themselves compelled to adopt, entails a considerable expenditure, the object sought is to select such a method of dealing with the sewage as will afford some return for the large outlay incurred. Hence it is that these gentlemen gave such large credence to the various disinfecting and deodorizing schemes put forward with so much effrontery. These modes of treatment were all exceedingly specious in character. They offered the perplexed and embarrased local boards a speedy extraction from all their difficulties, with the prospect of a large percentage by way of return in the first cost of the necessary works. The rest is known. The sewer authorities fell into the snare, and, after mulcting the unfortunate ratepayers, have been ultimately obliged to abandon all such vain projects, and betake themselves to the only true principle, viz, that of irrigation. Returning to the pollution of streams by the effluent water, the results at Croydon proved that after passing over the land, the liquid only added two grains of solid matter per gallon to the contents of the stream into which it was allowed to flow. Upon this rock all the deodorizing schemes have split. Granting that a very few of them can turn out a salable manure, which is very doubtful, not one of them can so purify the effluent water that it may pass into a river. So that, supposing they acomplish the first portion of the task, they altogether fail in the second. On the other hand, the utilization of sewage by irrigation accomplishes both. It utilizes the sewage, and purifies it at one and the same operation. It requires no chemical agents, no blood, bone, or charcoal. The agents it uses are those supplied by the growing plants themselves, which assimilate for their own benefit the manurial ingredients in the sewage, strain it, as it were, of its offensive properties, and, thus cleansed and purified, it may with perfect impunity be permitted to mingle with the waters of the nearest stream.

Having surmounted all preliminary obstacles, and grown crops in luxuriant abundance by the application of sewage to land, the question that now presents itself for solution is, which are the best paying crops to raise from sewage? It must not be understood from this that the best paying crop will be necessarily that which is produced most abundantly from land irrigated with sewage. Local circumstances, and the general character of the markets prevailing in the districts, will determine the crop which will yield

the greatest return. For instance, in a district where horse labor is exclusively employed, it would probably pay the farmer better to lay out his fields in grass than to sow them with cereals, notwithstanding the relatively higher value per acre of the latter. Thus the real paying value of a crop is no criterion of its powers of benefiting by the application of sewage. It is not our intention to discuss the particular influence exercised by local contingencies on the commercial value of sewage-grown crops, but to draw attention to the manner in which they are severally affected by its application, supposing other circumstances to be in common. For it is easily perceived that, owing to exceptional events, a perfectly factitious price might be given for any one particular crop, but at the same time this would not be a fair estimate of the effect of sewage upon it in comparison with other productions. It may also be fairly urged that in striking a balance the nature of the soil ought to be regarded, since one of the greatest advantages attendant upon irrigation with sewage is that it enables crops to be raised upon land which has generally been considered hopelessly sterile. It is a far greater triumph to grow a crop worth £20 per acre upon land which formerly produced nothing but weeds, than to raise a crop worth £30 per acre upon land which formerly yielded produce worth £20. There are, no doubt, some descriptions of soil which are so fertile as to yield a comparatively very poor return for the expense incurred in irrigating them with sewage. In a word, they do not require any manure. As a rule, the poorest kinds of soil which ordinary farming can do nothing with are the very ones to which to apply sewage, for two reasons. One is that they are otherwise totally unproductive, and the other that they will "stand," to use a common term, almost any amount of it, provided they be sown with rye grass. This is a point that local boards, and all who have to provide for the continuous disposal of large quantities of sewage, cannot lose sight of. Whatever crops may be selected, there must be a certain acreage appropriated to grass, in order that the remainder of the farm may not be injured by over or unseasonable doses. The too frequent repetition of a stimulant invariably does more harm than good, and defeats the very purpose it is intended to accomplish.

Taking into consideration only the acreage and the money actually paid for the produce of the ground, the highest price has been obtained by strawberries. They have been so fine in quality as to gain a prize at the Royal Horticultural Exhibition, and fetched the astonishing sum of £75 per acre. Strawberries pertain rather to the province of market gardeners than to that of farmers, but the example conclusively points out the almost universal scope of the irrigation principle. On the Romford farm, which constitutes the first instance of individual enterprise in connection with the sewage problem, onions have reached the price of £48 per acre. There is, however, a disadvantage connected with both these, as well as with some other descriptions of plants. They are rather precarious. Obviously it is better to select a plant or crop that is certain to yield a fair average annual produce than to put in the ground one which may give a very high return one season, and a very low one, or perhaps none at all, the next. As an example of "quick returns," spinach may be quoted, for some was sown, cut 29 days afterwards, and sold for £22 the acre. But as a counterbalance, another lot, sown subsequently, proved a failure, and was given to the cattle. If we were inclined to give the preference to any particular plants, we should select cabbages and mangold wurzel as likely to yield a good constant annual average. They are both of them certain of a sale, and are, besides, hardy, and not liable to be affected by contingencies that might prove detrimental to others of a more delicate organization. The difference between selling a crop on the ground and in the market is well exemplified in the case of some carrots grown on the Romford farm.

A portion of the produce was sold for £20 on the ground, and the remainder in the market brought £40 per acre. Against this latter price must be set the cost of carriage, which is frequently very high. It will be found generally to be preferable to sell the crop on the ground, instead of incurring the expense and risk of taking it to market, and this plan is the favorite with both seller and purchaser. While there is no doubt of the

success that has attended the application of sewage to oats, maize, wheat, and other cereals, there is a manifest tendency in sewage farming on the whole to cultivate green crops. They, in fact, yield the quickest return for the capital expended, and therefore it is but natural they should receive the greatest amount of attention on the part of the agriculturist. Moreover there is another reason for their adoption. The land appropriated to them does not require so expensive a method of laying out as in the case of cereals. The latter will demand considerable more care and science than have hitherto been bestowed upon them, before the proper treatment of them with sewage is thoroughly understood. They will not take the quantity that green and root crops will, and the periods of application must be regulated with a far greater degree of nicety.

LOCOMOTIVES vs. PORTABLE ENGINES.

From "Engineering."

Although during the past ten or fifteen years locomotive construction has made steady progress, and although much has been done to render locomotives more durable and better capable of dealing with the heavy work they have now a days to perform, yet we fear that, regarded purely and simply as steam users, they cannot be said to have undergone any material improvement. The use of steel for tyres, and many working parts, the adoption of larger bearing surfaces, and the use of improved means of lubrication, have lessened the cost of maintenance; the increased employment of the bogie in its various forms, and of appliances for giving the terminal wheels lateral play, have rendered engines better adapted for traversing curves, and have reduced wear and tear; and, lastly, the use of higher pressures of steam has enabled the power of engines to be increased, and has been attended with other beneficial results; but none of these improvements, important although they undoubtedly are, can be said to affect the statement which we have just made. It is true that by the employment of higher pressures of steam, locomotives have been probably enabled to develop a greater amount of work per pound of fuel burnt; but this is simply due to the increase of pressure *per se*, and can scarcely be said to be the result of the steam being more efficiently utilized after it leaves the boiler. It is not long since it was the fashion to advise portable engine builders to pay more attention to what has been done by locomotive engineers, but although this advice may still be given with regard to many matters of constructive detail, yet we fear that as far as the use of steam is concerned the advice will have to be reversed, and locomotive engineers will have to pay more attention to the practice of makers of portable engines. It may appear rank heresy to speak in this way; but the statement is, nevertheless, one well supported by facts. We do not mean to affirm that a common portable engine is a more economical steam user than an ordinary locomotive engine, but we assert that portable engines of the better class, such as are now sold by the leading makers to all who will pay for them, are, when the pressure of steam at which they are worked is taken into consideration, far more economical steam users than the best locomotives now in use. In other words, if the locomotive and the high-class portable engine were worked at the same steam pressure the latter would give out a considerably greater amount of work per pound of fuel consumed, than the former.

Stripped of its wheels and special appliances for enabling it to travel on rails and draw trains behind it, a locomotive is simply a non-condensing engine with unjacketed cylinders placed below the boiler level, and with the distribution of the steam effected by a common slide valve; and every portable engine builder of experience well knows that if he was to enter into a competitive trial with such an engine, he would be simply "nowhere." The experience of such trials has shown clearly the benefits derivable from the use of steam-jacketed cylinders, of separate expansion slides, and of arrangements for supplying the cylinder with steam in a perfectly dry state, and the teachings of such experience are now never

neglected by the leading makers of portable engines. Up to the present time the high pressures of steam used in locomotives, and the high piston speeds at which such engines are worked, have enabled them to hold their own; but as these sources of economy are gradually being incorporated in portable engine practice, locomotives will, we fear, be left behind unless something be done to improve them.

One of the first points which should, we think, be attended to, is the adoption of arrangements for insuring a supply of dry steam to the cylinders. There are, we know, many locomotive boilers which prime very little; but there are few which furnish steam in that thoroughly dry state in which it is so desirable to obtain it. In portable engines where the cylinders are situated on the top of the boiler, the carrying over of water with the steam is more easily prevented than when, as is the case with a locomotive, the cylinders are at a lower level; but inasmuch as in the latter instance the relative positions of the cylinders and boiler cannot be altered, special means must be resorted to for obtaining dry steam. Three methods of securing this dryness may be enumerated, thus: 1. The steam may be superheated on its way from the boiler to the cylinders; 2. The boiler may be worked at a higher pressure than would otherwise be employed, and the drying process may be effected by wire drawing; and 3. Mechanical means may be employed for separating the steam and water, and preventing the latter from entering the cylinder. The first of these plans—that of superheating the steam—has been tried on locomotives with but very indifferent practical success; and, indeed, the temperature of the high pressure steam now used can scarcely be much increased without giving rise to difficulties with the packing of the glands and lubrication of valves and pistons. The second plan is one which is often adopted unintentionally and it is no doubt effective within certain limits; but it can scarcely be said to be one worthy of extensive adoption. There thus remains the third plan, of mechanical separation, and this we believe, if properly worked out, will effect the desired results. It has long been known, that if a current of steam carrying water in suspension be suddenly diverted from its course, the momentum of the water will cause the latter to be carried forward in the direction in which the steam was moving before diversion; and if proper arrangements be employed, it can thus be collected and drawn off from the steam. "Separators" constructed on this principle have long been used by marine engineers and by some stationary engine builders with great success, and we believe their use on locomotive engines would be attended with excellent results. We may state here, that there is nothing new in this proposal to use separators on locomotives. More than twenty years ago, a separator, acting on the principle we have mentioned, was applied to the mouth of the steam pipe of a French locomotive by Mr. Edwards, and arrangements of a similar kind in modified forms have been since employed by other locomotive engineers. So far as we are aware, however, separators have only been applied to locomotives with a view of preventing the direct entrance of water into the steam pipe, and not with a view of further drying the steam on its way to the cylinders. The application of a separator to the mouth of a steam pipe, as was done by Edwards, is no doubt an excellent plan—far better, we believe, than any arrangement of screens and baffle plates—but in addition to this a second separator could be advantageously applied to the steam pipe just on entering the steam chest, or if this could not be conveniently done, fixed outside the smoke-box tube plate in place of the usual T-piece. The latter situation possesses the advantage, also, that any water collected in the separator could be allowed to run back direct to the boiler, while in the case of a separator placed at a lower level special arrangements would have to be provided for the discharge of this water. Separators, if properly constructed, offer no appreciable resistance to the flow of steam, and their cost is so insignificant that it is difficult to see any objection to their extensive use.

The next point — after getting dry steam to the cylinders—is to prevent condensation from taking place in the cylinders themselves during expansion. Superheating not being available, the only effective way of doing this is by employing steam jackets. Careful cleading of the cylinders and covers will, no doubt, do much; but no amount of cleading will

effectively replace a steam jacket even in non-condensing engines working with a moderate degree of expansion, and this fact the practice of portable engine makers has long proved decisively. In inside-cylinder locomotives the tops of the cylinder are to a certain extent kept hot by the hot gases in the smoke-box, but the dust and ashes which collect at the bottom of the latter soon form a non-conducting coating, through which but a slight transmission of heat to the cylinders can take place. In some outside cylinder engines, also, the hot gases have access to the outer surface of the barrels of the cylinders; but the arrangement is rarely such that any free circulation of the gases can take place, and thus the effect is, that those particles in immediate contact with the cylinders become cooled, and the latter merely become surrounded by jackets containing gases at a temperature far below that existing in the main body of the smoke-box. The latter temperature is in fact so high that if currents of the hot gases were made to circulate freely round the cylinders the effect would be to carbonize all the lubricating materials, and cause the destruction of the rubbing surfaces. The application of a practically effective air jacket—or rather gas jacket—to the cylinders being impossible, and superheating being unavailable, it follows, as we have said, that recourse must be had to steam jacketing if we desire to prevent condensation from taking place in the cylinders during expansion.

The principal objections which have been urged to the application of steam jackets to the cylinders of locomotives are: 1st, that in the case of inside cylinder engines there is rarely room for such jackets; and 2d, that in the case of outside cylinder engines the employment of steam jackets would increase the weight at a point where in many cases an excess of weight already exists. The first of these objections is to a certain extent unanswerable, and there are no doubt many instances in which inside cylinders could only be jacketed over but a small proportion of their surfaces—so small, in fact, as not to make it worth while to apply jackets at all. In the case of oustide-cylinder engines, however, the objection which has been raised is, we think, of but little importance. Portable engine builders now very generally cast their cylinders and steam jackets in one piece, and there is no reason why the same thing should not be done with the locomotive cylinders. Under these circumstances the addition of a steam jacket to a 16-in. cylinder of a length suitable for 2 ft. stroke should not increase the weight of the casting more than about $2\frac{1}{4}$ cwt. In the case of bogie engines having the leading wheels well forward, such an increase of weight would, of course, be of no importance; while in the case of engines having considerable overhang at the front end still lighter steam jackets might be formed by inserting a steel bush, say $\frac{1}{4}$ in. thick in each cylinder, the cylinder casting being chambered out around the bush to form the jacket. Steel linings or bushes have been applied to cylinders in this way by at least one firm of portable engine builders, and they have been found to wear exceedingly well.

In whatever way the steam jackets are formed, however, it is essential that they should be supplied with steam at the full boiler pressure, and that they should be kept clear of air and of the water arising from condensation; and it is in the fulfilment of these latter conditions that the chief practical difficulty of applying steam jackets to locomotive cylinders appears to us to consist. It being supposed that the steam jackets are completely distinct from the valve chests, a small pipe led to each direct from the boiler would, of course, serve to keep them supplied with steam at the full pressure; but to get effectively rid of the water arising from condensation is a more difficult affair. It would, of course, be easy to fit the jackets with blow-off cocks to be opened occasionally by hand; but such an arrangement would have the defect of being dependent for its efficiency upon the attention of the driver or fireman, and this we fear could scarcely be trusted for such a matter. A self-acting steam, or rather water, trap would no doubt serve the desired purpose better if it could be depended upon, and probably some form of steam trap now in use could be made available for the purpose, care being taken that the hot water blown off is delivered into the tanks. Probably the best plan, however, would be to allow the water from the jackets to drain down into a small tank, and to place either in this tank or in immediate connection with it, a small pump kept continually at work so as to return the water at once into the

boiler. This pump would, of course, have the full boiler pressure on both the suction and delivery side, and the work it would have to do therefore would merely be to lift the water from the collecting tank level into the boiler.

The question will probably be asked by some locomotive engineers, whether the additional economy obtainable by the employment of steam jackets is such as to warrant even the slight additional cost and complication which the use of such jackets involve? To this question a reply in the affirmative may in most cases be unhesitatingly given. Of course there are some locomotives employed on duty which necessitates their being almost always worked nearly in full gear, and under such circumstances the use of steam jackets would effect but very little saving. In all cases where engines are employed on work permitting them to be run with the steam cut off even as late as two-fifths of the stroke, however, the employment of steam jackets will be found to result in a marked advantage; and, in fact, if the arrangements are properly carried out, a saving of some 8 or 10 per cent. in the steam used while working expansively may be depended upon. In countries where fuel is dear, such a saving would be of especial importance.

We have now touched upon two points in which locomotive practice is open to improvement, and there are a few others connected with the use of the steam in such engines of which we also intended to speak here. The present article has, however, extended to such a length that we must postpone our further remarks until a future number. We shall, however, take an early opportunity of returning to the subject and directing attention to the points to which we have referred.

MOVABLE BRIDGES.

From "The Mechanics' Magazine."

The majority of bridges have a double duty to fulfil. It is not sufficient that they allow of the passage of loads over them, but they must also provide for their transit underneath. If a railway bridge crosses a road, it must do so in such a manner that its soffit shall be at such an elevation as will permit of the ordinary traffic being unimpeded. The same consideration must be attended to in the case of bridging a navigable river or stream. While, on the one hand, the primary object of the structure is to establish an uninterrupted communication from the one bank to the other, the necessity of maintaining open a certain amount of waterway for the passage of boats and vessels of the usual tonnage, is equally imperative. It is, in fact, a question of double headway. There must be in every instance of the nature referred to a minimum rise of the bridge above the water to accommodate the navigation. This quantity may vary between almost any limits, according to the particular exigencies of different localities. It may be as much as 100 ft., as in the case of the Britannia Bridge over the Menai Straits, or it may be only a few feet, and thus just allow a small rowing boat to pass beneath. Again, while this provision is unavoidable, it must not interfere with the level of the adjacent shores or banks. Should the minimum rise of the bridge necessary to preserve the traffic below be so great as to exceed a certain height above the level of the bank, the erection of the structure may become financially or constructively impracticable. In order to rise from the banks to the centre of the bridge the gradients might be so steep as to virtually forbid the work. Or, in order to reduce them to a practical slope, it might be necessary to build retaining walls and embankments of so heavy and expensive a description as to prove fatal to the entertainment of the project. Under these circumstances, when, for one or more of the reasons given above, it becomes impossible to adjust the heading or rise of the bridge so as to suit both descriptions of traffic, that is, above and below, another design of bridge must be adopted, differing in some particulars from those in general employment. Instead of being permanently fixed to their supports or abutments, they have free motion around one or more of them. Dividing all bridges into the two divisions of fixed and movable, it is under this

latter term we must include those we are about to draw attention to.

Movable bridges may therefore be considered to comprise all those which temporarily change their position in order to allow of the passage of one or other of the two descriptions of traffic they are designed to accommodate. The earliest specimens of movable bridges are probably to be found in the old drawbridge—the rude engineering appliance used in feudal and earlier times to open or cut off as might be desirable communication with the castle and the stronghold. There is, however, another description of bridge to which the same name is attached, which we shall refer to as we proceed. Under the general term "movable" may therefore be classed draw, swing, and swivel bridges. These subsidiary terms are frequently applied somewhat indiscriminately, but they nevertheless possess some distinctive features, and, as an example, a swivel bridge is generally one that swivels or slues round on a centre pier or support, and when closed spans two openings. But the same term, although perhaps with less propriety, may be applied to the case of one span, in which the whole bridge consists of two semi-arches meeting at the centre, each of which slues round on its own independent support. This represents the simplest case, which we will first draw attention to. It consists of one opening, and it is proposed to span it by a movable bridge which shall be composed of two pieces meeting at the centre, each of which can be moved on its support until it lies in a recess and will thus leave the opening perfectly free for the passage of the traffic underneath. Whatever principle may be adopted in the design, whether the arch or the horizontal girder, the first point to be borne in mind is that the one half is not supposed theoretically to receive any assistance from the other. Each half must be designed and constructed to carry its own share of the load without any reference to the other. The bridge consists, in fact, of a pair of cantilevers, which are sometimes in contact at their free extremities and sometimes separated. Unless the opening be of very insignificant dimensions, or to be necessary to maintain a uniform heading along the whole soffit, the most economical principle to adopt is that of the arch. Each half of the bridge will in that case be composed of a semi-arched cantilever, the proportions of the relative parts of which will vary according to the size of the span. The design we should select in these instances would be that of a wrought-iron braced semi-arch, and the following cursory analysis of the strains upon it will demonstrate that that material is the best adapted for the purpose. Regarding each half of the bridge as a cantilever, the strains will increase gradually from the centre, where they are very small, to the end, where they reach a maximum. But this arrangement varies with the relation of the separate parts of the design. At present it is considered to consist of an upper and lower flange, connected at suitable intervals by web of open lattice work composed of bars inclined at various angles to the horizon. The upper flange is horizontal and the lower curved. The radius of the latter will depend upon the width of the opening and the rise of the arch. It may almost be said to depend upon the former of these dimensions alone, since the rise is always a function of the span. The strains upon the upper flange are tensile in character, and, as already stated, accumulate in intensity from the centre to the support. Upon the lower flange the strains are compressive, increasing in amount in the same direction. Towards the end of the arch, these strains upon the two flanges are practically equal, but not so at the centre. The strains upon the bars in the web are compressive and tensile according to their position and angle of inclination, and are a maximum at the centre and a minimum at the abutment. Owing to the continually changing angle of inclination of the bars, there is no general rule for determining which of them are struts and which ties. This distinction must be made for each individual case in question. Were it not for the fact that the upper flange undergoes strains of tension, it would perhaps be more economical to use cast instead of wrought iron as the material for the bridge. But, apart from this consideration, the treacherous nature of cast iron renders it unreliable in instances where it is subjected to any vibratory or concussive action.

If instead of one opening there are two, with a pier in the centre of the water-

way, the same principle of design is equally applicable, but there will be a gain in economy, as can readily be shown. In the example of a single opening, it is necessary to prolong such semi-arch backwards, so to speak, on the abutments, and to load it with a heavy weight to counterpoise that of the cantilever. The part of the arch which is thus prolonged over the bearings is usually made with both flanges parallel, and constitutes a kind of small box, in which the counterpoise is placed. When there are two openings, and two of the cantilevers are connected together over the central pier, around which they swivel, they balance one another, and the counterweight can be dispensed with. Precaution must be taken to allow sufficient bearing over the central support, for it would not do to rely upon the theoretical balance of the two cantilevers. There must be some margin left, so that the equilibrium is not likely to be upset by any sudden impulse imparted to one of the projecting halves while the whole may be in motion. The machinery necessary for moving the bridge may be controlled by steam, hydraulic, or hand power, and will manifestly depend upon the scale upon which the design is constructed. As a rule, hand power is that oftenest employed. This follows from the circumstance that these descriptions of bridges are mostly used for establishing communication across the entrances to docks and basins, in which cases the openings are seldom more than 60 ft. or 70 ft. in width. If the bridge be designed on the plan already described, the half could be moved with facility by means of an ordinary winch. It is not our intention to enter into the details of the mechanical appliance required in particular instances, the more especially as there is no difficulty in effecting an arrangement which shall accomplish all that is needed. There are only two conditions to be fulfilled, but these must be carried out most thoroughly. One is, that the motion should be produced with ease, and the other with certainty. A bridge that "sticks" when it ought to open is a perpetual nuisance to all those who are in any way dependent upon its working properly. In that situation, it is alike useless to both parties, as it will accommodate neither the upper nor the lower traffic. We have known very serious delays to occur owing to the difficulty of getting a bridge to open when required.

There is another case of movable bridge to be considered, which is of a more expensive character than that described. It is that in which the whole bridge has to be moved from one support, and in which the horizontal girder is the principle of design adopted. When the moving is effected in a similar manner to that of the former example, this is merely an extension of the case, bearing in mind that the horizontal girder is substituted for the semi-arch. The length of the cantilever is doubled, on the supposition that the spans of both openings are equal, and a corresponding increase of weight to be moved and counterpoised takes place. It is almost an engineering axiom that, neglecting the foundations, or, what amounts to the same, supposing them to be favorable, it is invariably cheaper to build a bridge of two small spans than of one large one. Similarly, it will always be far more economical to construct a movable bridge in two separate halves than to make it in one entire span. This argument applies more forcibly in the case of movable bridges than of fixed, inasmuch as the former are really cantilevers, and not girders supported at both extremities. It is true that when a swing bridge which is entire throughout its whole span is brought to its bearings, it is then no doubt in the position of a girder supported at both ends. But at other times, when it is lifted off one of its supports and is put into motion, it is, so far as its own weight is concerned, a perfect cantilever. It is easy to perceive that in this case a complication occurs in the estimation of the strains. The bridge must be designed with respect to the load it has to carry, on the principle of a girder supported at both ends, and with respect to its own weight, as a girder fixed at one extremity and free at the other, that is, on the principle of the cantilever. The importance of this complication is only fully perceived when we come to consider the difference both in the nature and amount that prevails in the strains upon cantilevers and upon girders. In an ordinary girder the strains upon the upper flange are compressive, and tensile upon the lower; but when we convert this girder into a cantilever, these

strains are reversed, becoming tensile in the upper and compressive in the lower flange. It is scarcely necessary to point out that this fact would alone suffice to forbid the employment of cast iron in girders of this kind, which act alternately on one principle and then on another. But it is not in the flanges alone that the variation in the strains occurs. They also take place in the bars composing the web, which is perhaps of more importance still, as a bar that is designed and proportioned to bear safely a given tensile strain, will not carry the same amount when it is one of compression. The practical point to be looked at in these instances is the ratio between the weight of the bridge and that of the load it has to carry. This proportion will determine upon which principle the bridge must be designed, and what concession must be made to both of them. It has been hitherto assumed that the movable bridges slue or swivel round upon one or other of their supports, but there is another method of opening and closing the opening which is sometimes to be preferred. Instead of causing the bridge or half bridge to revolve upon its pivot like a door upon its hinges, it can be drawn backwards and forwards in a perfectly straight line. We might term these telescopic bridges. In a crowded waterway, where space was valuable, this plan would be found very advantageous, as no room would be required on one or both sides for the structure to swing back to the recess provided for it in the masonry. But this advantage is counterbalanced by the circumstance that a space must be kept clear on land in the rear of the bridge for it to be drawn back into. The question is reduced, therefore, to one of land *versus* water room, and the especial features of each example must decide it. There is no doubt that the plan of constructing the bridge all in one makes it steadier under traffic; but this defect in the semi-arch system proceeds solely from employing a faulty principle of securing the two projecting halves when they are in contact. When closed, the two semi-arches do partake more or less of the stability of the entire arch; but reliance must not be placed upon this, as any imperfection in the method of junction would at once destroy the value of the contact and place the two halves of the bridge in the position they should always be theoretically supposed to occupy.

DETERMINATION OF PURITY OF METALS BY THE FORM OF THEIR DROPS.

Translated from "Polytechnissche Journal."

At the May Meeting (1870) of the Prussian Society for the Advancement of Industrial Trades, Dr. Quincke, of Berlin, described a new method of determining the purity of melted metals, and of various chemical combinations by the height of the drops which are formed by them upon a horizontal surface. By the height of a drop, such as is formed by dew upon a leaf or by quicksilver upon glass, is meant the vertical distance of the horizontal plane from the vertex of the drop surface. This altitude is nearly constant, and is independent of the diameter of the drop if it is not greater than 20 millim.

If large flattened drops of the melted substances are formed at the lowest temperature possible, their altitude is the same as that of mercury, or it is obtained by multiplying the altitude of a large mercury drop by the square root of some integral number—2, 3, 4, etc.

The following substances give the same altitude of a melted drop as mercury: lead, bismuth, antimony, the chlorides, fats, sugar, etc.

An altitude about $\sqrt{2}$ times as great is obtained from melted ice (water), platinum, gold, silver, copper, phosphoric, carbonic and sulphuric salts, and glass; about $\sqrt{3}$ times as great from melted zinc and palladium (iron). Drops of melted sulphur, phosphorus, selenium, and bromine, are the lowest; their altitude being about $\frac{1}{\sqrt{2}}$ times that of mercury drops. The height and form of melted drops are the same as those of bubbles in the same substances under pressure of a horizontal plate.

The altitude of large flat drops or bubbles is less if their surface is covered with a thin coat of some fluid. A fluid coat less than the millionth of a millimetre in thickness is sufficient to reduce the altitude of melted drops in a sensible degree. A maximum of depression ($\frac{1}{4}$) occurs when the coat is $\frac{50}{1,000,000}$ of a millimetre in thickness, which is about $\frac{1}{10}$ of the length of a light wave. The presence of very small quantities of substances may be proved in this way to a degree of delicacy unequalled by any other method of observation except that of the spectroscope.

A trace of oil on a drop of dew or a bubble of air in water, and a trace of lead applied to a drop of melted silver, reduced the height from 4 to 2.8 millimetres, so that unpractised eyes could easily discern the difference. Substances which oxidize easily in the air should be melted and tried in some indifferent gas, like carbonic acid gas.

Large flat drops of iron from several mills, with surfaces coated with oxide, all had the same altitude of 5.2 millimetres. Workmen in foundries are in the habit of judging the quality of cast-iron by the form and condition of the drops. The speaker thought the careful investigation of the forms and altitudes of melted drops might prove an important aid in determining the properties of metals.

PROOF STRENGTH OF CHAINS.

From "The Building News."

Unless we regard the word chain to signify merely an assemblage of similar parts in which the total length bears a very large ratio to the lateral dimensions, the term suspension chain as applied to a bridge appears to be a misnomer. In all modern examples of suspension bridges the supporting chains consist either of numerous strands of wire twisted together so as to form a large wire rope, or of long bars united at their extremities by pins passing through eyes. The heads of the bar in which the eye-holes are made may be welded on the bar, or, by a new process, rolled at the same time with it. The latter is a very great improvement upon the former operation and should always be resorted to, notwithstanding the additional expense. It will be admitted that neither of these instances answers exactly to the popular idea of a chain, nor the signification which, constructively speaking, is generally attached to it. In a wide sense, anything that could assume the contour of the catenary curve would be a "catena" or chain, but as we are not at present inquiring into the derivation of the word, but into the practical value of the constructive agent it represents, we shall pass on to the more immediate subject of our article. Probably one of the most extensive and important uses to which chains are applied is in connection with shipping. Indeed, so well-known is the employment of iron in this capacity, that it is a very common occurrence to witness in the specification of a bridge, roof, or other engineering and architectural work, in which a large quantity of iron is wanted, the quality named as the "best cable iron." This naturally implies that the iron employed in the manufacture of cables is of a superior description, and when it is considered how many human lives, as well as much valuable property, is constantly depending upon the soundness and strength of chain cables, it is evident that they should be of the best material. Independently of these reasons, which are more than sufficient to render the above requirements indispensable, the nature of the strain to which chain cables are subjected is of a very trying description. It is far more severe than that which would result from the application of a weight merely requiring to be sustained at the end of the chain. The terrible and sudden jerks that cables are continually undergoing tax their strength and tenacity to the utmost. Engineers are well acquainted with the fact that a chain, or indeed any section of iron, will break with a much smaller weight when suddenly and violently applied, than it would when the same weight is "laid on" gently.

Most of our readers are probably familiar with the appearance of a chain cable. The links are oval in shape, and a small cross piece, technically termed a

stud, is inserted across them, in the direction of the minor axis or smaller diameter. This stud is of cast iron and its use is obvious. When the links are subjected to sever strain, they have manifestly a tendency to "draw," that is, to lengthen in the direction of the longer diameter, and to shorten in that of the shorter. The stud prevents this result and keeps the sides at their proper distance apart. The strain upon the link itself is tensile in character, but compressive upon the stud, whtch is thus made of cast iron, as the resistance of cast iron to compression, compared with that of wrought, is nearly double. On the other hand, the tensile strength of wrought iron is more than three times that of cast, so that each material is selected for the duty it can best fulfil. In previous articles relating to the strength of girders and various sections of iron, the influence of form or shape has been more than once conclusively shown to very considerably modify the actual resisting powers of the material. A very pertinent question in connection with the present instance arises. Does the conversion of the bar iron into the link of a chain increase or diminish the original strength of the metal? As a rule, iron is not improved, so far as either its tensile or compressive resistance is concerned, by any process of forging or welding. The science as well as the manipulative skill of the time have brought the two last mentioned operations to a degree of perfection that had not been attained to previously, but in spite of all the care and skill at our command, the "weld" can never be made so strong as the solid bar, or whatever other section of iron may be submitted to the process. At the same time, while it may be freely admitted that the "weld" is not equal in strength to the rest of the bar, it is a mistake to suppose that a "good weld" cannot be made. Some engineers and architects go so far as to set their face altogether against welds, but this is mere prejudice, and may very possibly arise from not possessing a thorough acquaintance with practical work and with the resources of a large and extensive "smithy." We have known instances in which a welded bar has been tested *á l'outrance*, and the solid bar has given way before the weld. This must be received as an exceptional case, but it nevertheless proves it is possible to effect this operation without deteriorating the resisting powers of the metal. To return to the question respecting the manner in which a bar of wrought iron is affected by its conversion into an oval-shaped link. Experience has shown, taking the average of superior and inferior qualities of iron, that a bar loses about a third of its ultimate strength by being converted into the link of a chain.

From what has been stated regarding the nature of the strains that chain cables have to undergo, and the serious liabilities contingent upon their parting, it will only be expected that the authorities should have taken some measures to insure their being of sound and durable manufacture. Without for a moment underrating the claims of the mercantile department, the Royal Navy has to be first considered. The weight and size of the vessels, the complement they carry, and the large outlay incurred in their building and armament, demand that due care should be taken that they are not lost for the want of good cables. With the view of providing this requisite, the Government has adopted a test or proof-strain for all chain cables intended for vessels belonging to the Royal Navy. If we suppose a bar of a given sectional area bent into the form of a link, the proof-strain demanded by Government is equal to $11\frac{1}{2}$ tons per sq. in. of the link. This test is calculated for one side of the link, so that the proof-strength of the whole link must be equal to the ultimate or tearing strain of the bar from which it is manufactured, supposing always the iron to be of superior quality. If it is not so, the link will not stand the test. This is a very severe test, but not more so than the nature of the case demands. In addition to the proof-strength of the chain being tested so far as regards the resistance to a tearing or tensile strain, it is also submitted to ordeals of a more trying character, and which are more in consonance with the actual description of strain it will have to withstand when undergoing real work. Heavy and sudden blows are inflicted upon some of the links while they are under strain, in order to test the value of their resisting powers to shocks and violent vibrations. As in the course of their duty they will have to undergo repeated strains of this description, the

precaution is not only justifiable but commendable. It may be urged that whatever may be the actual proof-strength of the iron it does not necessarily indicate the quality. A bar of iron may be sufficiently strong to withstand the proof-strain successfully, but its ultimate strength may be scarcely anything in excess. There would in such a case be nothing to spare, no margin of safety to rely upon, supposing that on some occasion or other the strain in practice should exceed the proof-strength of the material. Some test therefore is evidently required respecting the quality of the iron. In fact, if the quality of the iron could be ascertained, à priori there would be no necessity for any tests whatever, as iron of such a quality will always bear a strain of a commensurate intensity. The Government authorities test the quality of the metal in the chain cables submitted to them for ascertaining the proof-strength, by cutting out a link here and there from any part of the cable and breaking it. The character of the fracture, combined with the results of the other experiments, are sufficient and accurate indications of the quality of the iron, and the skill and care displayed in its manufacture and conversion into links. It cannot be too carefully borne in mind that the strength of a piece of iron is not an unequivocal test of its quality. A bar of iron that is not by any means homogeneous throughout its whole length, may yet be able to resist the testing strain put upon it, simply because the strain may not affect its weakest part. It is uniformity of strength and of resistance that is wanted in all iron-work, more especially in such an example as a chain, in which the slightest weakness in one of the component parts will cause the failure of the whole. A single faulty link will cause the cable to part, the ship to be wrecked and the crew and passengers to be lost. It is scarcely possible that the proof-strength of a chain cable could be tested link by link, except so far as that the transmission of strain throughout the whole may be regarded as a valid criterion; but by cutting a few links indiscriminately a fair estimate may be unquestionably made of the soundness of the entire length. Should a single link prove defective while undergoing the ordeal, the whole chain is not condemned on that account, but a new link is substituted, and the cable submitted to a further test. Manufacturers rarely send chain cables for testing that are below the standard, for the best of reasons: in the first place, it would be to no purpose, and in the second they would damage their own reputation for good work.

ON THE GIBRALTAR CURRENT, THE GULF STREAM, AND THE GENERAL OCEANIC CIRCULATION.

By DR. W. B. CARPENTER, F.R.S.

From "The Artizan."

The author commenced by an allusion to the investigations carried out for 3 years past, with the aid of the Hydrographic Department of the Admiralty, into the nature of the deep sea, and detailed the observations conducted by himself and Commander Calver of H.M.S. Porcupine, on the outflowing undercurrent at the Straits of Gibraltar. He showed on what insufficient observations the supposition of a current flowing outward from the Mediterranean had hitherto rested. An outflow of this nature was a necessary hypothesis; for the excess of saltness caused by the great surface-evaporation (naturally of pure water only) from the Mediterranean would otherwise be most sensibly felt in the waters of that sea; and this was not compensated by rainfall and rivers, or by the water flowing in to restore the level, which consisted of Atlantic salt water setting inwards, in a surface-stream, at the rate of 3 miles an hour. It was singular that the shallowest part of the Straits was not where they were narrowest, at Gibraltar, but much farther to the west, between Capes Trafalgar and Spartel; the sea-bottom slopes westward from Gibraltar, where it averages about 400 fathoms, to the western extremity, where the depth is scarcely 50 fathoms on the northern, and 200 fathoms on the southern half. After repeated observations, aided by the in-

genious mechanical contrivances of Commander Calver, the existence of a deep-water current setting outwards was finally established. It was true the stream must thus be supposed to flow up-hill along the sea-bottom from Gibraltar to the shallow ridge westward (the true limit of the Mediterranean basin); but this was shown to be the natural action of flowing water under such circumstances. Dr. Carpenter then explained that this interchange of water between the Mediterranean and the Atlantic was in accordance with a simple physical law, and that the same law, in its wider application, threw a new light on oceanic circulation and marine currents throughout the globe. As the surface water of the superheated Mediterranean ascended by evaporation, leaving its saline constituents behind, the remaining water, becoming denser and heavier by its increased saltness, sinks beneath the less salt Atlantic water flowing inward by the Straits, and is eventually forced outward as an under-current, as proved by the recent observations. If the accession of fresh water by rain and rivers in the Mediterranean had equalled the amount evaporated from the surface, instead of being much the reverse, there would have been no current and counter-current at the Straits of Gibraltar; and if the fresh-water supplies had been greater than the evaporation, there would have been a surface-current outwards of the lighter water. This last hypothetical condition is precisely that of the Baltic in regard to the North Sea, in which case there is a surface-flow of fresh water outwards and an under-current of heavier sea-water inwards. It was obvious that a like circulation of waters, the lighter above and the heavier below, in opposite streams, must take place in any case in which a want of equilibrium between two columns of water is constantly maintained, whatever might be the agency producing it. A great difference of temperature at two extremities of a great ocean must cause two such currents to be set going on a vast scale; for, as in the cold area, water contracts and becomes heavier by the cold, its level must sink, and the general oceanic level be continually maintained by a flow of warmer and lighter water from the warmer areas of the same or adjoining ocean. The recent investigations had supplied results in accordance with this hypothesis. Such circulation of oceanic water being universal, Dr. Carpenter had found reason to doubt the received opinion of the Gulf Stream being the direct cause of the set of warmer water towards North-Western Europe and into the Arctic circle; the Gulf Stream was rather a local accident of the oceanic circulation, resulting from the configuration of the land past which it flowed, and its existence as a stream much beyond the banks of Newfoundland was not proved. A beautiful experimental illustration of opposite currents was exhibited by the author. At the extremities of a long glass trough, filled with water, upright tubes were fixed; one of which was filled with ice, and the tube at the opposite end heated by a gas jet. On blue coloring matter being inserted at the cold, and red at the warm end, the two separate streams became visible, the red near the surface and the blue below.

Australian Telegraphy.—The advices received with respect to the progress of the great overland Australian telegraph are considered satisfactory upon the whole. Nothing very definite appears, however, to have been yet attained. When the last mail left Adelaide, Mr. Todd, superintendent of telegraphs in Australia, had not yet returned from the neighborhood of Mount Margaret, the furthermost outpost of settlement on the southern side of that portion of the Australian continent under the jurisdiction of the South Australian Government. Mr. Todd's desire was to see the great work undertaken fairly put in hand before he left Mount Margaret.

New Zealand Mails.—On dit that the New Zealand Government proposes to enter into an arrangement with an American Steam Shipping Company for the conveyance of mails from Great Britain *via* New York, the Central Pacific Railroad and San Francisco. The subsidy is to be £75,000 per annum.

The English papers speak doubtfully of the entire success of the Sherman Steel Process.

PROPORTION BETWEEN STRENGTH AND SIZE OF IRON.

From "The Mechanics' Magazine."

It has been established by experiment that small sizes of iron are proportionately stronger than larger ones. In other words, two bars of iron, containing each one square inch of sectional area, will be stronger than one bar containing two square inches. This discrepancy is not confined to bars and rods, but extends to iron of various forms. Thus, small forgings are generally tensilely stronger proportionately than large ones, although it must be admitted that the difference in strength which may be manifested depends very much upon the skill and care bestowed upon the workmanship. Uniformity of strength in any single piece or compound structure of iron must be synonymous with a homogeneous consistency of all the parts. Thus, if a bar or plate of iron be not homogeneous throughout, its strength will be only equal to that of its weakest part. As it is always more difficult to manufacture large sections of iron than small ones, so that the element of homogeneity be maintained, it is evident that the latter have the best chance of being endowed with uniformity of strength. Arguing solely upon these grounds, it would seem that only very small sections and sizes of iron should be used in order to obtain the maximum value out of the material. The minimum sectional area that can be given to iron intended for constructive purposes, is that of wire, and consequently by analogy iron wire should be used instead of bars, rods, and other forms. However correct this purely theoretical argument may seem, there are many practical reasons which render the carrying of it into execution impracticable. In the first place, the theoretical assertion will only hold for those cases in which the strain to which the material is to be subjected is of a tensile character. Obviously iron wire by itself or in a multiplicity of strands so as to constitute a wire rope, is altogether unsuitable to withstand strains of compression. It is utterly deficient in lateral rigidity or stiffness. Viewed in the most favorable light, namely, that in which it is acted upon by strains only of a tensile nature, there are many objections against its employment, notwithstanding its proportional greater strength than bars of the same sectional area. It will be shown presently what these objections are, and how they tend in practice to counterbalance the advantages which theory confers upon the use of wire ropes. But, in the first place, it will be interesting to notice what is the difference in the actual tensile strength of iron wire and that material in the shape of bars and plates. The unit of comparison will in all cases be that of one square inch of sectional area.

The strength of iron wire, similarly to that of other forms and sections of the metal, will vary with the quality, and can be procured good, bad, or indifferent, but in making an estimate of it, the correct method is to take such a limit only as has been attained in actual practice. It is frequently the custom with engineers to specify that the iron to be supplied for bridges and other works of construction shall be of a superlatively good quality and able to stand a test of the severest character. This we believe to be a mistake. Any very extraordinary excellence in one particular is sure to be more than equalized by a deficiency in another. Some of the tests insisted upon by engineers are simply ridiculous, and merely serve as a premium for ingenuity in evading them. The tensile strength of iron may be regarded in two different lights—one in which the strength of a single wire is taken into consideration, and the other in which that of a number of them combined in the form of wire rope is the object sought. It has been proved that an iron wire having a sectional area of 0.0078 square inches, bore a breaking tensile strain of 0.28 tons, which would be equal to 36 tons per one square inch of area. The tensile strain of the best iron bar cannot be taken at more than 26 tons, so that there is a large preponderance in favor of the wire. But a still greater difference is manifest in the case of a rope or number of strands, and a well known instance is that of the iron cable supporting the Niagara Bridge. The tensile strength of the cable per square inch is equal to 44.5 tons, and there are 60 wires to one square inch of section. Consequently the sectional area of each wire is 0.0166 square

inches, and its ultimate tensile strain, supposing all the wires to be of uniform strength, would be equal to 0.738 tons. We may now compare these two cases. Without taking into consideration the question of relative sizes, the ratio between the wire having a sectional area of 0.0078 square inches, and that of 0.0166, would give the ultimate strength of the latter equal to 0.60 tons instead of 0.738 tons. This slight excess must be attributed to the circumstance of a number of wires being bound together, thus constituting a practical corroboration of the motto, "in union there is strength." In estimating the strength of iron wire, care must always be taken to ascertain whether it has been annealed or not, as the process seriously diminishes the resistance of the metal to a tensile strain. Moreover, the average tensile strength of ordinary iron wire will not equal that which has been given here, but when it is required for important engineering works there is special care bestowed upon its manufacture. Like every other form of iron, wire and wire rope can be had of bad quality, unless it be specified to the contrary, and precautions taken to be certain that the specification is complied with.

We have now to consider the practical part of the question, and inquire into the reason why it is that, with so high a power of resistance, iron wire and wire rope is not employed more frequently in construction. It has been already mentioned that it is useless as a material for resisting strains of compression. Whether in single or manifold strands, it is alike unsuited to strains of that description. But bearing in mind the high tensile strain which it will withstand when properly manufactured for the purpose, one would expect, at least, that advantage would be taken of this property it possesses, whenever the opportunity occurred. But experience and the practice of engineers demonstrate that the contrary is the fact. There may be some excuse for not employing iron wire as tension bars or ties in many engineering structures, because under certain conditions attending the passage of a heavy rolling load, the tension bars may be subjected to strains of compression, which, although slight in amount, would be fatal to the adoption of wire as the form of material for them. Again, it is not merely this want of resistance to strains of compression that unfits it for many positions in which it might be safely and economically employed, but also the very small power it possesses of resisting a tendency to sag. So long as a straight bar, rod, or wire is of reasonable length and strained tightly, it will be practically free from sagging or deflection. But when it becomes very long and the strain upon it slackens, it will be certain to sag. It is manifestly for this reason that king rods are employed in iron roofs when the ties are horizontally extended from the end of one rafter to that of the other. So long as the tie rod of a roof is horizontal and supports no flooring or ceiling of any kind, the strain upon it is a direct pull, and it is supposed to undergo no transverse strain except that resulting from the action of its own weight. That there is a tendency in all ties to drop or sag, is shown by the fact that in iron roofs where flat bars are used for the ties, they are invariably placed on edge so as to give the bar the advantage of the depth in resisting the tendency to deflect in the centre. In most bridges and other structures the various parts are rarely subjected to only one description of strain. If the load were always stationary and uniform, then the strains upon the different members would always be of the same character; but loads varying in amount and position completely destroy this simplicity of action, and, moreover, sometimes very much complicate the design. There are only two descriptions of structure in which the nature, although not the amount, of the strains is independent of the amount and position of the load. They are the arch and the suspension principles. In the former the whole undergoes strains of compression, and in the latter, of tension. In suspension bridges, therefore, we appear at last to have arrived at the proper sphere for the application of iron wire. Yet iron wire is not by any means exclusively used in suspension bridges. Many engineers object to its use altogether, notwithstanding the undoubted fact that the cables of the Niagara Bridge stood a breaking weight of 44½ tons per square inch of sectional area. It might be inquired, why is this? Surely a section of iron that can stand a tensile strain of nearly double that which the same material in another form can, is the proper section to employ in situations

where its distinguishing characteristic is brought into play. It is just here that one of those instances occurs where the theoretical man is at fault, and unless he combines practical knowledge with an acquaintance with science, he inevitably comes to grief. Omitting all consideration of single wires, the question is reduced to that of ropes or cables in which a number of strands are wound or twisted together, and in which the strength of the whole is dependent upon that of its individual components.

There are two grave objections to the employment of iron cables. One is that as the strength of the entire rope is made up of the strength of all the wires together, it is quite possible that some of these may be stronger than others, and some weaker. The testing of the cable is not a criterion of the separate value of its components, and consequently some strands may be more severely strained than others. Again, by the nature of the manufacture, it is not an easy matter to insure that a uniformity of strain shall be imparted to every wire in the cable, supposing that they are all equal in tensile resistance. There is a great difference in the fracture of a cable and a bar or rod of iron. The latter will break right in two, so to speak; but in the former, failure ensues by the parting of the strands, clearly intimating that one of two circumstances takes place. Either the strain is unequally distributed, or, what is probably the case, the resistance of the wires is not uniform, and consequently the weaker ones yield and the cable parts before its ultimate resisting powers are called into play. In all combinations of parts which tend to constitute a certain total sectional area of metal, the strength of the whole is estimated at so many tons per square inch of that area, and the only difficulty to be overcome is, to insure that each part shall be able to bear its proper share of the load. Otherwise, upon the well known engineering principle that no constructive design is stronger than its weakest part, if one part or member be weaker than another, the whole structure suffers in consequence, and will yield to a less severe strain than it ought to do. It may be mentioned that tests *a l'outrance* are not necessarily an accurate indication of the strength of a cable, beam, or girder. Examples of construction, after being tested very severely, have subsequently yielded to a strain of considerably less severity. The second objection urged against the use of iron wire cables is that it is impossible to obtain any idea of the amount of corrosion that may be in progress in the interior of it. Some of the wires might be eaten away to almost nothing without the least symptom of the evil being apparent superficially, and, what is worse, it could not be detected without practically destroying the cable. Undoubtedly the use of iron rope is attended, omitting the objections alluded to, with economy in suspension bridges, but it is nevertheless not universally employed in them. It is used in the instance of Lambeth Bridge, which was designed with especial regard to cheapness and ugliness, but in the handsome structure at Chelsea, suspension bar links are substituted with great advantage to the architectural merits of the bridge. Summing up the whole subject, it must be admitted that while the smaller sections of iron are unquestionably proportionally stronger than larger ones, yet in practice this theoretical superiority is counterbalanced by other disadvantages which preclude that extended application of the principle which, under other circumstances, might be considered advisable. Obviously the carrying out of this diminution of section to an extreme point would terminate in a *reductio ad absurdum*, for it would indicate that the maximum economical results would be obtained by using iron in the form of mere threads or filaments. But strength to resist any particular description of strain is not the only property demanded of a constructive material. A certain degree of stiffness and inherent solidity is also required. Moreover, the smaller the section of iron the greater the effect of corrosion and other extraneous causes of deterioration. We know an instance in which an iron bridge was erected over an arm of the sea, and in which the bars were increased from $\frac{1}{8}$ in. to $\frac{1}{4}$ in. in thickness beyond that which the strain rendered necessary, on purpose to allow for the action of corrosion by the sea air.

The deepest excavation in the United States is a copper mine near Lake Superior. It is 1,300 ft. deep.

THE SHERMAN PROCESS.

From "The Engineer."

About twelve months since, Mr. J. E. Sherman, an American steel-maker, came over to this country to introduce a new process of manufacture intended to improve inferior qualities of iron. Mr. Sherman commenced his operations at Chatham, where he worked for our Government, it is said with success. Subsequently he visited various establishments in this country, and tried his process on a very considerable scale. Reports of his progress have found their way into many local papers. Some of these condemned, others praised the process; but it does not appear that any articles have been written on the subject as yet by men who, possessing a competent knowledge of the manufacture of iron, also saw the process carried out, and the resulting iron tested properly. A few months ago Mr. Sherman's agent called at our office and showed us samples of wrought-iron and steel, apparently of excellent quality, produced by the Sherman process; but as we did not see these made, we declined to take any notice whatever of the matter until such time as the inventor might be in a position to supply us with the fullest information. We confess that we regard with the utmost doubt all processes—and they can be counted by the hundred—which are intended to make naturally bad iron good by the aid of chemicals, or, to use an ironmaster's phrase, by "physicking." On the other hand, it would be obviously improper to draw a fixed line and assert that any method of manipulating iron beyond that line must be a failure. We, therefore, reluctant to condemn the Sherman process as we were to praise it, suspended our judgment until we knew more about it. During the last few months Mr. Sherman has been at work for Sir John Brown & Co., Sheffield, the firm placing every possible facility in his way for experimenting, and on Friday and Saturday last we visited the works by Mr. Sherman's invitation, and made ourselves acquainted with the details of the entire process as applied to the manufacture of Bessemer steel, crucible steel, and puddled iron. Mr. Sherman placed every possible opportunity of obtaining information at our disposal. He made no secret of anything. He left the conduct of the experiments in our hands; in a word, we cannot speak too highly of his straightforward dealing from first to last. The experience of two days with a new process like this is, however, not sufficient to enable us to pronounce any decided opinions of value as to its merits. We shall therefore confine ourselves strictly to a statement of what we saw done, begging our readers to bear in mind that it was absolutely impossible that the results of the experiments could be vitiated by unfair dealing, or even by the bias of an inventor's opinion. Those who peruse this article will therefore be able to form an opinion for themselves as to the merits of the process, which we for the moment decline to give. What a private individual thinks can affect only himself; an expression of our sentiments under the circumstances might be unfair to Mr. Sherman or to the great body of iron manufacturers in this kingdom.

Before going further it will be well to explain precisely what the Sherman process is. Mr. Sherman takes for a basis the argument that the practical difference between what is known as good iron and bad iron is, other things being equal, that good iron is nearly free from sulphur and phosphorus, while bad iron contains either or both, the first making it red short, the latter cold short, while very bad iron, containing both sulphur and phosphorus, is both red short and cold short. Reasoning from these premises, he assumes that if the sulphur and phosphorus can be eliminated, bad iron may become very good. But the affinity for iron of the two elements we have named is known to be excessively strong. In order to get rid of them something must be introduced into the puddling furnace, the crucible or the converter, which will not only have a greater affinity for sulphur and phosphorus than iron has, but which also admits of being driven off at a high temperature. Mr. Sherman has sought this something for eleven years, and he claims to have found it in iodine, almost any compound of which answers his purpose, but he prefers to use it in the form of iodide of potassium, to use the old, and among

ironmasters as yet best known, chemical terminology. He asserts that the iodine combines with the sulphur and phosphorus, hunts them up throughout the mass of melted metal, combines with them, and carries them away partly in the cinder, partly in the gaseous state due to a high temperature. Mr. Sherman has told us the precise proportion of iodine which it is necessary to use, which is very small, but as it would not be difficult to practise his invention without his knowledge, and so defraud him of his royalties, we do not consider ourselves at liberty to publish the minute details of the process on which it is claimed its success in great measure depends. We write this article, however, in such full possession of them as could be acquired by Mr. Sherman's instructions, and the fact that we actually applied the process ourselves at Sir John Brown's works.

On Friday morning we commenced operations by witnessing the application of the process to the manufacture of Bessemer steel, two charges being blown in our presence. The method of introducing the "physic" into the converter is extremely simple. A short length of pipe is screwed vertically into the elbow where the trunnion of the converter joins the blast main ; this pipe is fitted with two stopcocks, placed a few inches asunder. The lower one is closed just before blowing begins, and the upper one opened ; the iodide of potassium in coarse powder, is then poured through the opening in the first cock, into the space between it and the second cock. The upper cock is then shut, and blowing begins ; after the process has reached a certain point, determined by spectroscopic examination of the flame from the converter, the lower cock is opened, the iodide of potassium at once falls into the trunnion and is blown right through the molten metal by the blast. The following particulars of the second charge we saw blown will give an idea of the nature of Mr. Sherman's operations :

The charge consisted of nearly 7 tons, thus made up : Millom hematite, 25 cwt.; West Cumberland hematite, 25 cwt.; Askam hematite, 20 cwt.; Harrington hematite, 40 cwt. ; Glengarnock common Scotch, 20 cwt.; Spiegeleisen, 9 cwt.; the ordinary mixture used being the same, with the exception that 20 cwt. of Cleator hematite takes the place of the Glengarnock pig, which is rendered available by the aid of the Sherman process. It was, in short, introduced experimentally. The charges for both the blowings we saw were the same. We did not take the time spent in blowing the first charge. Blowing began with the second charge at 11.4 A. M.; at 11.15 the cock was turned and the iodide of potassium introduced. Blowing ceased at 11.21, and the spiegeleisen was introduced at 11.22. The charge was immediately tapped into the ingot moulds without further blowing. Throughout, the pressure of blast was a little over 13 lbs. on the sq. in., and the iron, no doubt, from the presence of the Scotch pig, worked exceedingly hot. At the moment the iodine was introduced, the flame escaping from the mouth of the converter became augmented in volume and intensity. We cannot better describe the change than by stating that the flame became more solid. The proper time for introducing the iodine is just about the moment when the carbon lines first appear in the spectrum. At the instant the iodine is introduced, all the lines become strengthened ; but the effect produced is so transient, that it would require an extended series of examinations to determine exactly what is the nature of the change effected in the spectrum of the flame. This, we may add, is a point of much importance, to which spectroscopists would do well to direct their attention. We believe we are correct in stating that Mr. Browning is now engaged in the construction of an apparatus by which the spectrum can be thrown on a small screen to be examined by direct vision. Such an apparatus, if portable and handy, cannot fail to prove valuable to steel makers.

As soon as this charge was blown, we proceeded to test the process in the puddling furnace ; but inasmuch as we resumed operations with the converter, on Saturday, it will be more convenient to say here all that we have to say about the Sherman process as applied to the Bessemer process, and then turn to the puddling furnace and the crucible. It will be understood that Mr. Sherman is working in the converter tentatively. The 1 ton of Scotch pig was introduced experimentally, but before that several ordinary charges were blown with iodide of potassium added. These were rolled

into rails. The opinions we heard expressed in the rail mill were to the effect that the percentage of waste was reduced by about one-half; that the metal worked kindly, and finished well. The statistics of four 7 ton charges ran thus: The charges produced 83 rail blooms weighing 640 lbs., or 23 ton 1 cwt. 1 qr. 20 lbs. These blooms were rolled into 83 rails 30 ft. long, and weighing 57.5 lbs. to the yard. Eighty of the rails were good, three were defective. About 20 cwt. of scrap was produced in cutting the blooms to the proper length for the rails, and about 4 tons of iron were lost in blowing the four charges, heating the blooms, etc. On Saturday we saw a portion of the charges containing Glengarnock pig worked under the hammer. During Friday night four rails had been rolled from the only ingots ready at the time, with perfect success. The ingots worked under the hammer as perfectly as any Bessemer ingot could work. We had some of the crop ends forged into bars about 3 in. sq., under a 10 ton hammer, without the slightest symptom of splitting or cracking.

On Saturday morning Mr. Sherman advanced a step further, and blew some charges with an increased proportion of inferior iron. Each charge consisted of Glengarnock Scotch pig, 40 cwt.; Harrington hematite, 40 cwt.; West Cumberland hematite, 30 cwt.; Askam hematite, 20 cwt.; Spiegeleisen, 9 cwt. We witnessed the blowing of one charge only. The blast was turned on at 10.14. The iodide of potassium was introduced at 10.25, with, as before, an immediate augmentation in the volume of flame, and the operation was completed at 11.30. We did not see any of the ingots made on Saturday worked up, but we have since been informed that they were quite satisfactory.

We shall now recount our experience of the use of iodine in the puddling furnace. The iron was made on Friday, and on Saturday the tests of the bars were carried out by Mr. Hunt, who conducts all the tests made at Sir John Brown and Co.'s works.

Two puddling furnaces in what is known as the "south forge" were placed at our disposal. These furnaces are numbered respectively 10 and 11, and we decided that a charge should be worked into wrought iron in No. 10, and another charge worked into what is called at Sir John Brown's "steel iron"—in other words, puddled steel—in No. 11. The whole difference in quality was due to the fact that the metal was drawn rather green to make puddled steel. In every other respect as regards fettling, etc., the process of manufacture was identical. As so much depends on the method of fettling practised, we took special care to ascertain the nature of the system adopted, which was, as far as we could see, precisely the same as that used in working the other furnaces. The puddlers were left strictly to their own devices, receiving no instructions either from us or from Mr. Sherman. The furnaces are of the ordinary water bosh type, each delivering the products of combustion into the vertical flue of a stack boiler. The method of proceeding was as follows:—The bottom of the hearth was cooled down with a few shovelfuls of cold water. When this had dried off, about 30 lbs. of ball furnace cinder were put into the furnace close to the throat; the rest of the hearth was then fettled in the ordinary way with hematite ore in paste. Just before charging, two small shovelfuls of mill scale were spread evenly over the hearth bottom, and the pig was then introduced. The iron used was Linthorpe No. 4, a metal made almost in the centre of the town of Middlesbrough, costing 40s. to 45s. per ton, and never used by itself in ordinary practice at Sir John Brown's, as it is found to be both red and cold short. The charge weighed as nearly as might be $4\frac{1}{4}$ cwt. No. 11 furnace was charged at 11.52. The iron was all melted about 12.24; at 12.37 it began to rise, but was not quite boiling. At this point we ourselves, at Mr. Sherman's request, introduced the dose of iodide of potassium, which was wrapped up in paper, put into a ladle, and covered with a few handfuls of common salt, which is used to confine the iodine and prevent its rapid volatilization. The damper was dropped for a few minutes. The immediate result of the introduction of the iodide, which was thrown in through the rabble-hole, and rapidly stirred into the metal, was the production of a multitude of tiny jets of white flame from the surface, which quickly disappeared. The metal worked hot and boiled well. It was puddled carefully, but not with more care

than should always be bestowed on the operation. At 1.22 the first ball was drawn. The charge was worked into four balls, which were taken at once to the steam shingling hammer. They shingled kindly and well, with the discharge of much fluid cinder. Still hot, the blooms were put into a ball furnace with a cinder bottom, brought to a good wash heat, and then taken to a second hammer, where they were reduced to billets about 4 in. square. No. 1 ball split under the hammer. Being the first ball drawn it was probably a little too green. It was returned to the ball furnace, re-heated, and hammered again. The second hammering it bore quite well. Balls Nos. 2, 3, and 4 worked as well as possible. They were then, while still hot, charged into a second furnace, re-heated, and rolled into bars $3\frac{1}{4}$ in. $\times$ $\frac{5}{8}$ in. One of these bars was cut up, piled four high, and rolled into a billet $1\frac{1}{4}$ in. square.

Furnace No. 10 was fettled and charged as No. 11 in all respects. The iron was put in at 12.4. It was all melted about 12.27. The iodide was put in at 12.55, and the first ball drawn at 1.45. The subsequent processes were identical with those already described, with the exception that all the balls worked very well, both under the hammer and the rolls. It may be well to state here that the iron made in the south forge is used exclusively for conversion into steel for railway and other springs, of which the Company make enormous quantities. The Shermanized iron was treated in all respects—save the piling of one bar from the furnace—as though it had formed part of the regular production of the forge.

In order to test the quality of the iron produced we had all the bars marked. Those made in No. 10 furnace we called No. 2; but those made in No. 11 furnace No. 1, the latter being puddled steel, the former wrought iron. Bars of No. 2 and No. 1 were then cut into lengths of 22 in. and taken to the blacksmith's shop. No. 2 bore bending cold to an angle of about 120 deg., or nearly double, when a small crack appeared. The other end of the bar was then heated, split, and submitted to the well-known ram's horn test. A small crack appeared in one of the legs soon after bending commenced, but it did not extend. The other leg bent very kindly. The result of this test was pronounced quite satisfactory. The bar was then heated and punched, a succession of drifts being driven through the same hole —the bar being kept hot all the time— until it had reached a diameter of $4\frac{3}{4}$ in., or $1\frac{1}{2}$ in. greater than the width of the bar, the iron being reduced to a section of little more than $\frac{1}{8}$ to $\frac{1}{4}$ of an in. at each side, without a crack. This may be taken as conclusive evidence that the metal was not red short.

A similar test bar of No. 1 underwent the same process, which it stood as well. The ram's horn test, indeed, gave better results, as there was no crack.

One of the square billets from No. 2 bore bending double, cold, without crack or fracture of any kind save a small split in the side due to the imperfect welding of the pile in the rolls.

We then had a test bar of No. 1 planed on the edges, its dimensions being $2.01 \times .73$ in. This bar was then broken in the machine used by Mr. Hunt for carrying out all the tests made daily at Sir John Brown & Co.'s. The following are the results:

Test length	10 in.
Area of bar	1.4673 in.
Total strain	41.5 tons.
Strain per square inch	28.28 tons.
Elongation	20.2 per cent.
Length of longest inch	1.32
Reduction in area	25.17 per cent.

The fracture was partly crystalline, partly fibrous; the line of demarcation being well marked across the thickness of the bar. About $\frac{2}{3}$ths were crystalline, moderately fine; the fibres were rather coarse, but very clean.

A bar of No. 2, almost precisely similar, was then broken. It gave way at the first essay, with a very moderate strain, close to the gripping jaws. On examination a bit of fire-brick was found embedded in the iron at this point, which, of course, explained the breakage. As the bar was still long enough, a fresh hold was taken, and the test proceeded, with the following result:

Test length	10 in.
Area of cross section	1.3668 in.
Total strain	33.5 tons.
Strain per inch	24.6 tons.
Length of longest inch	1.18.
Elongation	11 per cent.
Reduction in area	15.2 per cent.

This bar was in every respect the worst of the whole lot, as was evident

from the character of the grain. It had probably taken up impurities from the falling of some small portion of the crown of the furnace during the operation of puddling. Although we do not regard it as a fair sample of the iron produced, we, in pursuance of our resolution to state exactly what results were obtained, think it right to place the particulars of the test before our readers :

From the billet made from the same charge we obtained the following results, which, it will be seen, go far to prove that test bar No. 2 was not a fair sample : A piece of billet iron No. 2, 22 in. long, was turned down for about 10 in. of its length to a diameter of 1 in. This was placed in the testing machine and broken. It gave way exactly in the centre of its length.

Test length	10 in.
Total strain	21 tons.
Strain per square inch	26.61 tons.
Length of longest inch	1.5.
Elongation	23.7 per cent.
Reduction in area	37.45 per cent.

The fracture was clean and good, partly fibrous, partly crystalline.

A test bar of No. 1, the same in all respects as the preceding, gave the following results :

Test length	10 in.
Total strain	21 tons 15 cwt.
Strain per square inch	27.18 tons.
Elongation	22 3 per cent.
Longest inch	1.57.
Reduction of area	43.2 per cent.

This bar stretched very equally, as shown by the numerous points of contraction found in the length of the piece. We refrain, at present, from pronouncing any opinion on the quality of iron manifesting the properties it was proved to possess by the foregoing tests.

We have now to consider the process as applied to the manufacture of crucible steel. We must premise that although we witnessed the production of crucible steel by the Sherman process, we did not see the steel so made tested. As, however, we are enabled to lay before our readers the results of the tests verified by Mr. Hunt, this is a matter of no consequence whatever. That the figures we give below are as truthful and accurate as possible is simply beyond question.

On the morning of Saturday, 2 crucibles were charged in the ordinary way with 50 lbs. each of iron cut off the bars described in our last impression. The iron was put into the white-hot crucibles with a charging funnel. The moment it was all in, a small quantity of iodide of potassium wrapped up in paper was thrown into each crucible on the cold iron. The lid was immediately placed on the pot and the furnace filled up with coke. The sole difference which we observed, or which existed, between the manufacture of the ordinary pot steel and Sherman pot steel was embodied in the facts, first, that the iron used was all made in the way already described from Linthorpe pig ; and, secondly, that a very small quantity of iodide of potassium was put into each crucible. That is all. The steel when properly melted was "teemed" into 2 ingot moulds. The resulting ingots were subsequently tilted into bars, specimens of which we have seen. It is indisputable that the quality is excellent, as shown both by the appearance of the bars and the following tabular statement of their qualities:

Tests of Steel Bars, Sherman Process. Crucible Steel—Linthorpe Pig.

No 1.

Test length	10 in.
Dimensions	0.49 in. × 0.49 in.
Breaking strain	11.25 tons
Per square inch	46.85 tons
Elongation	9 5 per cent.
Reduction in area	31.69 per cent.

No. 2.

Test length	10 in.
Dimensions	0.51 in. × 0.51 in.
Breaking strain	11.50 tons
Per square inch	45.09 tons
Elongation	12.3 per cent.
Reduction in area	41.89 per cent.

No. 3.

Test length	10 in.
Dimensions	0.55 in. × 0.55 in.
Breaking strain	16.50 tons
Per square inch	54.54 tons
Elongation	10 91 per cent.
Reduction in area	30.04 per cent.

Two bars an inch square were then turned down for a length of 22 in.in the middle, to a diameter of $\frac{1}{2}$ in. These were then twisted across cold by direct torsion. They both broke in the middle with $5\frac{1}{2}$ complete turns. A test bar $\frac{1}{2}$ in. sq. was then coiled cold into a helix of 7 coils, with an internal diameter of $5\frac{3}{8}$ in. The metal was pronounced by the men in the tilting-house to work as kindly and as well as any steel could work. A portion of this steel is now, we understand, being

used in the fitting shop in the shape of chisels and lathe tools, so far with excellent results.

We are enabled to supplement the information first published on this subject with the following particulars of tests of steel bars and rails made by the Sherman process in the converter. The bars were forged and tilted out of the croppings from rail billets before referred to. It will be as well to give the figures applying to the rails first :

Test of Steel Rails, Sherman Process—Bessemer.

No. 900 Blow.—Single-headed rails, 57 lbs. per yard. Weight of one ton falling 15 ft.; bearings 3 ft. apart.

1st test, one blow of monkey, deflection 5½ in.
2nd " " " " 5⅝ in.
3rd " " " " broke

No. 901.

1st test, one blow of monkey, deflection 5¾ in.
2nd " " " " 5⅞ in.
3rd, 2 blows, 1st blow 5¾ in.; second blow 10½ in.

No. 3 test rail blow 901 already bent 10½ in., put upon end ; 2 blows of 1 ton each, 7 ft. fall ; rail broke. Total deflection, 13 in.

No. 921.—Test rail. First test broke.

The rail No. 921 was over-carbonized, possibly from the introduction of too much spiegeleisen, and was unfit for permanent way, being too hard and brittle. That it was, notwithstanding, admirably suited to other purposes, will be seen from the following figures :

No. 901 Bar.

Test lengths in all cases, 10 in.

Dimensions	0.58 in. × 0.575 in.
Breaking strain	14.50 tons.
Per square inch	43.48 tons.
Elongation	13.7 per cent.
Reduction in area	41.91 per cent.

No. 921 Bar.

Dimensions	0.56in. × 0.56 in.
Breaking strain	15.25 tons.
Per square inch	48.62 tons.
Elongation	11.5 per cent.
Reduction in area	32.52 per cent.

No. 945 Bar.

Dimensions	0.46 in. × 0.46 in.
Breaking strain	10 75 tons.
Per square inch	50.80 tons.
Elongation	6 per cent.
Reduction in area	22.88 per cent.

Cold Twists, Bessemer Bars.—No. 901 Bar.

Test bar, four turns. This test bar, plain all the length, ½in. square, broke in the die for holding.

Cold Twist.—No. 921 Bar.

Tests bars, inch square ends, turned down to ½in. diameter, for 22 in. in the middle, stood five turns each. Bars broke in the middle.

Cold Coiling Tests.—Bessemer Bars.

No. 901 test bar, ½ in. square, coiled into helical coil or spring). Four coils ; inside diameter, 3⅜ in.

No. 921 test bar, ½ in. square. Five coils; inside diameter, 3⅜ in.

We have now placed our readers in possession of all the information we have been able to acquire so far concerning a process which it is thought by some people is only second to that of Bessemer in importance. If the theory of the action of iodine held by Mr. Sherman be correct, it is very possible that he will work a small revolution in the manufacture of wrought iron from inferior pig. We still reserve a decided expression of opinion as to the ultimate value of the process ; but it does not follow that we must, to carry out this intention, reserve our opinions as to the action of iodine on melted iron. We therefore state definitely that if Mr. Sherman is right, and if it is accordingly true that iodine either removes phosphorus from iron or renders it innocuous, then modern chemistry is all wrong. To assume, in the first place, that the small quantity of iodine used by Mr. Sherman can eliminate the phosphorus, is to assume an impossibility. Phosphorus exists in iron only as some one of the seven known phosphides of iron, all of which are extremely stable compounds. It is well known to chemists that the action of iodine on these compounds only differs from that of chlorine and fluorine in that it is less energetic, yet Hochstätter found the fusion of phosphides of iron with fluoride of calcium had no effect on them as regards the elimination of the phosphorus. Why, then, should iodine ? Iron may be dissolved in nascent chlorine obtained by decomposing hydrochloric acid with a battery, but the phosphide of iron and nickel contained in the iron is not decomposed; oxygen, we know, leaves the phosphides almost untouched. If, then, fluorine, chlorine, and oxygen are without effect—nay, even fail to manifest the smallest tendency to have an effect—why should we expect iodine to be active ? If at any temperature iodine should expel phosphorus, it must do so because of the superior affinity of the iodine over that of the phosphorus for iron; but this reaction could only take place after all the uncombined iron had been saturated with iodine. But such an event is impossible in the Sherman process, because the quantity of

iodine used is so small. As regards sulphur, much the same reasoning will hold good.

In point of fact, however, there is reason to believe that the iodine in the Sherman process does not remove all, or possibly any of the phosphorus, as the following analysis of one of the "blows" which we witnessed, and particulars of which we have already given, goes to show. The analysis was made by Mr. G. G. Barker, chemist to Sir John Brown and Co. :

Analysis of Bessemer Steel after being treated by Mr. Sherman's Process. Blow made with one ton of Glengarnock Pig Iron.

	Charge.	Steel after the spiegel has been added.
Combined carbon...	0.426	0.38
Graphite.....	2.419	Trace.
Silicon	3.08	Trace.
Phosphorus	0.104	0.045
Sulphur.....	0.09	Trace.
Manganese.....	0.592	0.625

The phosphorus is here reduced nearly one-half, but it is highly probable that a similar reduction would have taken place whether the iodide of potassium was or was not introduced, and as it is, quite enough remains to impair the quality of the steel if the element retains its normal activity. An analysis of steel iron made from common pig, gives the following results:

	Linthorpe.	Eglington.	Sondley.
Iron.....	99.450	99.34	99.51
Combined carbon.	0.10	0.13	0.12
Graphite.....	Trace.	Trace.	Trace.
Silicon.....	Trace.	Trace.	Trace
Phosphorus	0.105	0.087	0.06
Sulphur.....	Trace.	Trace.	Trace.
Manganese.....	0.340	0.443	0.305

Sample of Cast Steel made from Linthorpe Steel-iron.

Combined carbon.....	0.910	Per cent.
Phosphorus.....	0.055	
Sulphur.....	Trace.	

Mr. Barker adds: "It appears, by comparing the rather large percentage of phosphorus with the mechanical results, that a portion of the phosphorus must be neutralized by Mr. Sherman's process," a very natural conclusion under the circumstances.

Seeing, then, that not only is it a physcal impossibility, according to existing chemical knowledge, for the iodine put into the converter or the puddling furnace, to eliminate the phosphorus, but that direct experiment proves that chemical knowledge is so far accurate, we find ourselves on the horns of a dilemma. That the iron treated by the Sherman process which we saw tested, was thereby improved, is, we think, if not clearly proved, still highly probable. The question then remains to be settled, to what is the improvement due? The phosphorus being there, why does it not operate for evil? The only answer is, that the element is in some way rendered innocuous. One explanation is that the phosphorus becomes amorphous or allotropic. That iodine will render phosphorus allotropic under certain circumstances is known, but the theory completely breaks down when applied to the Sherman process. Phosphorus will not remain amorphous at any temperature near that of molten iron; therefore, to imagine that it can retain a state of allotropism in the puddling furnace or the Bessemer converter is simply absurd.

There is one solution of the difficulty which we put forward as being much nearer the truth. It is that the iodine used by Mr. Sherman has no effect whatever. That, in a word, the whole virtue of the process lies in the potassium and not in the iodine contained in the mixture he uses. At the temperature present in the converter and the puddling furnace it is quite possible that all the iodine simply escapes as vapor, and that an alloy of iron and potassium is formed, which, reacting on the phosphide of iron, forms a phosphide of potassium that remains entangled in the metal, and does little harm. If this theory be correct, as good results will be obtained by blowing a few ounces of carbonate of potash through a Bessemer converter, as can be had from the use of the iodide of potassium used by Mr. Sherman, and the experiment is so simple that it is highly desirable it should be tried.

It is just possible, after all, that the laws known to apply when small quantities of metal are treated in the laboratory may become modified when larger masses of metal are dealt with, though this is unlikely. It is, we think, pretty evident at all events that the iron we saw made by

the Sherman process was better than chemistry would lead us to anticipate. We have definite statements, too, from the other side of the Atlantic, that fluorine is being used in the Henderson process—an account of which, by the author, we reproduce in another page—in the elimination of phosphorus with much success; yet, as we have seen, laboratory experiments go to show that fluorine can have no appreciable effect on phosphide of iron. It would be absurd to say that chemistry is a finite science, that its professors can never be at fault, and, therefore, that there is nothing in the Sherman process. All that we can say positively is that if Mr. Sherman is right, then chemists have a good deal to learn. That he is right so far as we have seen is apparently indisputable. It remains for us to watch the progress of the process, and see whether he will continue to be right. Neither Mr. Sherman nor any other individual living knows enough just at present about the chemistry of iron, to be justified in dogmatizing on the matter.

RIVERS: THEIR FUNCTIONS AND THEIR TREATMENT.

From "The Builder."

The universal diffusion of water is necessary to existence; and perhaps no process in the great economy of nature subserves more important and useful ends. The moisture evaporated from the ocean is carried inland, and the clouds, descending in rain, "drop fatness" upon the soil. This duty done, the configuration of the surface collects the drainage water in rivulets, the primary supply for the support of animal life; and the union of the latter in the lowest valleys produces the mighty stream, which, completing the rotation, returns the water to its parent sea.

It is no uncommon figure of speech to impute to great rivers the parentage of the dwellers on their banks; and our own familiar "Father Thames" readily occurs to the mind as an instance. Nor is the epithet undeserved; for in all times the great seats of population, industry, and wealth have been placed, for the most part, on the banks of a navigable stream. To the river, the city owed its existence, its protection from danger, its supply of the first necessaries of life, its communication, and its trade. The fairest and most stately buildings adorned its banks, and the highest and noblest denizens displayed their pomp upon its waters. The parent stream was held in affection, approaching personal regard; and in ancient times the feeling of veneration thus created has even led to its deification:

"O Tiber, Father Tiber,
To whom the Romans pray."

The great streams, as already stated, are formed by the union of many rivulets, and thus represent the result of the *drainage* of the entire district or watershed to which they appertain. The first function, therefore, of a river is the drainage of the land; and it is needless to dilate on the universality and importance of this duty. When, from either natural or artificial causes, it is inefficiently performed, the surface becomes moist or swampy, the atmosphere miasmatic and insalubrious, and the country more or less unfit for the habitation of man.

It has also been stated previously, that the great seats of population and trade have been usually placed upon navigable streams, to which, in fact, they owe their origin; and, which form, also, the earliest, and in no few instances the most important highway of a country.

It follows, therefore, that the second great function of a river is to supply the means of internal navigation.

In considering, therefore, the treatment of rivers, with a view to their artificial improvement, these two functions, viz., drainage and navigation, have evidently to be kept in view; and almost all the works of river engineering have been directed to one or other, and not unfrequently to both together, of these objects.

It is proposed, accordingly, to discuss briefly in this paper the usual conditions found existing in large streams, from their point of discharge to their source; to describe the causes of impediment to the proper discharge of their functions;

and the best available means whereby such difficulties may be diminished or removed.

A frequent source of impediment to the navigation of rivers arises from the formation of bars at their mouths. This most usually occurs from the circumstance that the bed of the river is composed of soft material, which the running water removes and carries down with it in suspension to the sea. Then the flow of the stream being arrested, and its silt-bearing waters brought to a stand-still, in consequence of their impingement on the sea, the material in suspension subsides or settles down at that point, and forms a bar across the entrance of the river. As the greater or less velocity of the current will determine the distance to which it is carried out to sea before its flow or motion is sufficiently checked to allow the silt to deposit, so will the distance of the bar to seaward from the mouth of the river be regulated.

The first effect of this process is naturally to shoal the water or form a bar at the entrance of a navigable river, to an extent generally limited by the circumstance that the river water must at all times force its passage over or through the bar into the sea. Nor are the impediments to navigation always confined to such shoaling alone. When the mouth of the river is in an exposed situation, the bar is liable to become, as it were, an artificial foreshore, over which breakers are formed and roll with violence; and the depth of water on the bar is then further diminished by the extent to which the trough of the wave descends below the level of the smooth water. The surface of the water will, in such a case, frequently pass with great rapidity from a state of quiescence to one of agitation, and remain so for a lengthened period; detaining vessels, in many instances, for weeks together, from the impossibility of their crossing the bar with safety. In fact, many frightful shipwrecks have occurred in attempting such a passage with an insufficient depth of water to keep the vessel afloat at the lowest level; the ship being alternately lifted on the crest of the waves and lowered in their trough till her bottom strikes on the bar, when the pounding motion thus produced on the heavy mass of her hull almost instantly breaks her to pieces.

It has been stated that the diminution of the depth of water over a bar is generally limited by the circumstance that the river current must at all times force its passage either *over* or *through* the bar into the sea. The former of these conditions usually occurs and continues whilst the river waters are at their average volume and normal state; when the tendency of the bar is to shoal to the utmost limit, at the same time increasing its width or transverse section from the continual accumulation of deposit. The latter condition, on the other hand, takes place at the period of heavy floods, when the increased velocity and volume of the current tends to sweep away the previous accumulation and to remove the material of the bar further out into the deep sea water. The force of floods, therefore, when thus available, is the most potent agent for keeping open the navigation; and the usual object of engineering works in such a case is to confine the force of the flood within artificial boundaries or limits, and to direct or discharge it fully upon the bar; when from the expansion of the river-current or otherwise, that effect did not previously take place.

When the object of works of this nature is to remove an existing bar, they usually consist of two embankments or walls in continuation of the natural banks of the river, carried out seaward to such a distance as to prevent the diffusion of the flood water, and the consequent diminution of its force, before it impinges upon the bar. Perhaps one of the most interesting examples of works of this nature, which have been recently constructed, is that from the designs of Sir Charles Hartley, for maintaining a navigable depth through the bar of the Sulina mouth of the Danube, the particulars of which it is now proposed briefly to describe.

The shore of the Black Sea, at the point where the Sulina mouth of the Danube discharges into it, lies nearly north and south, and a littoral current of about a knot an hour flows from north to south along the coast. There are no tides in the Black Sea, but the level of the water along the shore is considerably influenced by the action of the wind, varying from 18 in. below the mean sea-level when the wind is from the west, or off the land, to 2 ft. above that level when the wind is

from the east, or off the sea. The Sulina branch of the Danube discharges at right angles into the sea, its navigable width being about 300 ft., and it discharges a quantity of water, varying from 4½ million cubic ft. per minute during times of greatest flood, to a little over half a million cubic ft. per minute during the dry season. The amount of deposit held in suspension by the river water during these times (from which deposits the bar is formed) varies from about 1 in. in the foot, or 1-12th during the flood, to about 1-40th during the dry season, of the cubic quantity of water in the river.

The phenomena of the formation of the bars are sufficiently curious. In ordinary seasons, the matter held in suspension by the river waters is precipitated near the shore, at a short distance seaward from the mouth of the river; and this effect, frequently continuing for months together, forms a regularly increasing bar across the entrance. At the time of high floods, however, the river waters having a greatly increased volume and velocity, force their way through the bar further out into the sea, removing it either wholly or partially into deeper water, and leaving the river entrance comparatively free from obstruction. But the flood waters themselves, which carry a greater quantity of matter in suspension, form bars in their turn farther from the shore, as well as of considerably greater magnitude. Also, if the flood be accompanied by a westerly wind coinciding in direction with it, and lowering the sea-level as already described, this bar will be formed still further out to sea, owing to the greater penetration of the river waters; while, on the other hand, if the wind be eastward, or contrary to the flow of the river, the level of the sea is raised as above mentioned, the velocity of the flood waters is more effectually checked, and the deposit of the matter in suspension takes place more rapidly, resulting in the formation of a bar nearer to the shore, and of greater magnitude than in the former case. On the subsidence of the flood, these deep-water bars are gradually lessened, or partially removed, by the littoral current, and the formation of bars near the shore from the ordinary river waters proceeds as before, until another flood again sweeps them out to sea.

It will be readily understood from this description, however, that the whole mass of the deposited material at the river mouth is continually on the increase, even though a navigable passage through it may be maintained either by natural or artificial means. The result is, in fact, a constant encroachment of the land upon the sea; and the delta of the River Danube, which discharges through no less than eleven mouths into the sea, has attained the dimensions of about 40 miles from east to west, and about 50 miles from north to south; and covers an area of considerably more than 1,000 square miles.

The system of improvement of the Sulina entrance recently adopted by the European Commission of the Danube is described by the engineer as being that of guiding "the river waters across the bar, by means of piers projected from the most advanced dry angles of the mouth; or, in other words, that of concentrating the strength of the river current on the bottom of the proposed seaward channel, by an artificial prolongation of the river banks into deep water." For this purpose, two piers were built out into the sea in continuation of the river banks, the northern pier being 4,631 ft. in length, and the southern pier 3,000 ft.; the formation of the shore allowing the south pier to be commenced at a considerable distance seaward of the shore end of the north pier, and the latter also projecting out somewhat further. These works had naturally the effect of concentrating the river current, and directing its whole force on the existing bar; and they have been carried out to such good purpose, that the navigable depth has been increased from 9 ft. to 17 ft., to the immense improvement of the navigation, and consequently of the trade of the locality.

It may be understood that in works of the above nature the effect is but temporary, as the deposit of silt ever continues, and that in a period of time varying according to the circumstances of the case, a further prolongation of the piers will become necessary; and this applies to all rivers carrying matter in suspension to the sea.

The above effects are considerably modified where a river discharges into a tidal sea. In this case, the river waters, instead of descending with a regular flow, are penned back, and rendered stationary by the rising or flood tide, and are therefore

liable during its continuance to deposit the matters held by them in suspension in the upper reaches of the river, instead of at its mouth. In general, however, the entrance of such a river is kept comparatively open by the tidal scour, especially when the ebb tide, uniting with the fresh waters, creates a strong downward current. Such a current is also less liable to be brought to a stand-still by impinging on the sea; as, instead of being arrested by the salt water, it continues its flow in conjunction with the retreating tide, to which its waters are united.

The above, however, though the most common, are not the only cause of the formation of bars. It also frequently happens that deposits are formed at the mouths of rivers by tidal silt-bearing waters which are checked in their regular flow at that point. The Thames is a notable example of this effect. The flowing tide runs along our eastern coast in a southerly direction from the north of Scotland to Essex, and the flowing tide through the English Channel runs at the same time in an easterly direction to beyond Dover, and, turning northward from this point, it meets the northern flow above mentioned.

These opposing currents arrest each other's velocity opposite the mouth of the Thames, and enormous deposits in consequence take place in the estuary into which the river discharges, though, fortunately for the navigation, the scour created by the tidal waters, passing into and out of the Thames itself, is sufficient to keep open several navigable channels at its mouth, where sufficient depth of water for the largest vessels is constantly maintained.

Again, in the Dornoch Frith, which is the most northern estuary on the east coast of Scotland, there is a remarkable example of the formation of a bar by tidal waters. The mouth or outlet of the frith forms a semicircular bay of considerable extent, the diameter of which is open to the sea; but at the upper end or head of the semicircle, the prolongation of the frith is contracted abruptly to about $\frac{1}{4}$ of that diameter, and it continues its course inland with that diminished width. The consequence is that the flowing tide from the open sea is guided along either shore of the semicircular bay till it gradually forms two littoral currents, which meet each other in opposite directions at the head of the bay, opposite the point where the frith is suddenly narrowed, as above explained. These littoral currents, thus meeting from opposite directions, bring each other to a comparative stand-still opposite the point where the upper or narrow portion of the frith discharges into the bay, where they deposit the silt which they carry in suspension. Thus the curious effect is produced of the formation of a bar opposite the mouth of the upper portion of the frith, but which is formed from the deposit of silt by the external waters of the sea, instead of by the internal waters of the river.

This effect, of course, ceases on the commencement of the ebb tide, when the current is turned in the opposite direction. The tendency of the ebb is to remove the newly-formed bar; but as there is only the water contained in the upper or narrow part of the estuary available for this purpose, which is considerably less in quantity than the flood setting in through the bay, the bar permanently continues. It is found, moreover, that the depth of water over the bar is greatest after the occurrence of heavy land-floods acting in conjunction with the ebb-tide.

A bar is also formed in the same locality, but from a different cause, at the sea entrance to Cromarty Frith, immediately south of the Frith of Dornoch, just referred to. This entrance consists of a narrow chasm between two lofty headlands, of about a mile and a half in length; on the landward side of the entrance the frith suddenly expands into a bay of several miles in extent. The tidal waters, in consequence, rush through the narrow passage with great velocity, and deposit their silt on either side of it when their velocity is checked. The flood-tide deposits its silt in the inner bay, and especially around its shores, where the velocity of the current is the least; and the ebb-tide deposits its silt at a short distance to seaward of the mouth of the narrow passage, forming a bar in a manner precisely similar to that of a silt-bearing river. In the latter case, the fact is observed, that the greatest amount of bar, and consequently the least depth of water over the bar, is found in the direction which is taken by the main current of the ebb-tide; the quantity of silt carried by

the ebb being, of course, the greatest in that direction.

The effect of the tidal waters in maintaining a navigable channel, either over a bar or through the deposits in the lower reaches of a river or estuary, is, in the majority of instances, of far greater importance than the effect of the river waters themselves. Any engineering works, therefore, in such a locality, whereby the tidal scour may be effected, usually require the most careful consideration ; and in the case of projected works in this country are made the subject of minute investigation by the public authorities.

Such works have generally one of the following objects in view, namely, to improve the navigation, to form lines of wharfs or quays, or to reclaim for cultivation the lands lying on the foreshore of the river or estuary, which were previously submerged at high water.

For maintaining the navigation, it is usually advisable to admit the greatest possible quantity of tidal water into the river. The reason of this is manifest. As the river approaches the sea, its inclination diminishes, until it becomes nearly or entirely horizontal, and the velocity of the upland waters is diminished in proportion. This causes them to deposit their sediment, and to diminish the depth for navigation. But the tidal waters, by creating what may be termed an artificial current, correct this tendency and keep the channel clear, and the larger the body of tidal water admitted into the river, the more effectually this duty is performed.

Though, however, it may be assumed as a rule that the larger the quantity of tidal water the better, yet this rule may admit of some exceptions. For instance, if any portion of a river subject to tidal influence be expanded to a considerable width, so as to form a sort of lake at that part, the tide during its flow will be partially occupied in filling this expanse, and proportionately prevented from rising or flowing into the portion of the river immediately above, which is thus deprived of the full advantage of the tidal scour. In such cases it may be more advisable to contract artificially the channel of the river to its normal dimensions, even though the capacity for receiving tidal water should be somewhat diminished. In short, the benefit of the tidal influence is measured, in one sense, by the cubical quantity of tidal water which the river receives ; and, in another, by the height or distance up the river to which the tide ascends, and the balance of greatest advantage is arrived at when due regard is paid to both considerations, either of which may predominate according to local circumstances and requirements.

The most successful results in the improvement of tidal rivers have been attained in many cases by simultaneously regulating the width of the channel and deepening the bed of the stream. The latter process may be effected in soft soils, such as the alluvial plains of India, by means of the river current itself, which when properly regulated, will scour its own channel to the required extent. But it frequently happens that river shoals acquire, in the course of time, such hardness and consistency that no improvement of the channel will suffice for their removal. In such a case, the principle usually adopted by engineers is to remove the cause of the formation of shoals by measures tending to increase the velocity of the current, and then to remove the shoals themselves by dredging. The latter process has the further advantage of increasing the capacity of the tidal channel, and of allowing the tide to flow freely in both directions, which has the effect of increasing both its height and depth. Dredging has accordingly been very extensively practised in navigable streams; and in the Thames alone it is stated that about ten millions of cubic yards have been thus removed from the bed of the river.

The usual means of regulating the width of rivers is by the construction of longitudinal or training walls on either bank. They are built, according to circumstances, of masonry, concrete, or timber piling, or formed by earth embankments pitched with stone where exposed to the running water. Such embankments are also frequently formed of alternate layers of earth and fascines, or bundles of faggots, which makes a cheap and good construction for rivers of moderate velocity. Where the space or foreshore to be reclaimed is very large, and the filling at the back of the training walls would consequently be expensive, it is usual in the first instance to run out timber groynes from the bank at intervals, about half-

tide high, across the space which it is proposed to reclaim. These constructions intercept and gradually collect between them a considerable portion of deposit from the river; and when this is done, the training walls are built. The most successful instance of a river improved in this manner is, perhaps, the Clyde at Glasgow, where the depth available for navigation at low water is stated to have been increased by the measures above-described judiciously applied, and by dredging, to no less an extent than from 2 ft. to 20 ft. These works, and the importance of the port resulting from them, are, perhaps, the greatest triumph on record in this branch of engineering.

In some cases, as in the Dee at Chester, groynes, as above described, have been applied without further constructions. But this treatment has been found to produce irregularities in the course of the stream, and, in fact, to be prejudicial to the improvement of navigable rivers rather than the contrary.

The above are the principal natural phenomena at and near the mouths of navigable rivers with which engineering skill and science have been required to deal. It is now proposed to proceed upwards, and review the causes of impediment to navigation and drainage which usually occur in the higher portions of streams.

It has been already stated that the lower reaches of rivers generally flow through a flat country, and consequently with a comparatively sluggish current; and this applies to the portion both within and immediately above the tidal influence. It is a curious natural fact that the tendency of a river under these circumstances is not to preserve a straight course, but to form for itself a winding or circuitous channel. The current, in the first instance, is probably deflected by some artificial obstruction, such as a partial hardness of the soil, from its straight and proper course, and cuts its channel in the direction of least resistance. The weight and force of the stream, instead of moving along the middle of the river, as they would do in a straight channel, are by this means directed sideways, so as to impinge on one or other of the banks, whence the stream is again deflected (like a billiard-ball striking obliquely upon its cushion), in an angle corresponding to the angle of incidence. This takes place in nature upon the largest scale; and the effect of these irregularities is, in many cases, surprisingly regular, forming a continuation of alternate or S bends, of equal curvature. Of this the Thames presents many notable examples, and the great rivers through the alluvial plains of India are often wonderfully regular in the form and extent of their sinuosities.

Where the river is of this nature, the outer or convex side of the curves or bends is naturally the deepest; and the inner side is liable to shoal. Between the bends the line of main current and of deepest water naturally sets across the river, from the outer curve on one side or bank, to the succeeding outer curve on the other.

It is evident from the above description that the current will tend continally to abrade or bite upon the outer curve or bank at these bends, and to deposit and shoal the course of the water at the inner curve. The continued abrasion in the former case also tends to widen the bed of the river, to diffuse the stream over a larger space, and to weaken its force in proportion.

The effect of such sinuosities is also to increase the length of the channel to a large extent, and to diminish its rate of fall in proportion, thus aggravating the evil of insufficient velocity to which rivers in flat countries are liable. These remarks are even more applicable to the reaches above the tidal influence than to those below it, as the volume of the river water, and its consequent capacity for maintaining a clear channel, are usually very much smaller than that of the tidal stream.

The straightening of bends, so as to form a direct and uniform channel, is of course the most obvious remedy for this evil; and it occasionally happens, when a bend is very circuitous, that a very short artificial channel will save a comparatively great distance in length of river. These operations, however, involve the necessity of many precautions to insure their efficiency. The inclination of the channel in the new work of course becomes greater as its length is diminished, and the velocity of the stream is proportionately increased, involving the probability that the bed of the new channel may be scoured to a much greater extent than that of

the old, and that the material so removed may be deposited in the lower portion of the stream, where the current resumes its original rate of flow. Moreover, at the lower junction of the new and steeper with the old flat channel, the increased velocity of the stream receives a sudden check; and the current will expend its force, unless efficient measures be taken to prevent it, in ploughing or tearing up the bottom at the point where its velocity is so checked, and in throwing up the excavated material beyond in a bank or bar across the river.

The scouring power exercised by a river on various soils is, of course, measured by the velocity of the water at the bottom, which, owing to friction, is much less than the surface velocity.

It may therefore be interesting to state the comparative surface and bottom velocities of rivers, and the effect of those velocities in scouring various soils.

Surface and Bottom Velocities in Feet per Minute.

Surface.	Bottom.	Surface.	Bottom.
20	5	260	192
40	16½	280	210
60	30	300	228
80	45	320	245
100	60	340	263
120	75	360	280
140	92	380	300
160	108	400	315
180	125	420	333
200	142	440	351
220	158	460	368
240	176	500	405

Effect of different Velocities of Water in Scouring various Soils.

15 ft.	per minute	will scour	fine clay.
30 ft.	do.	do.	fine sand.
45 ft.	do.	do.	coarse sand.
60 ft.	do.	do.	fine gravel.
120 ft.	do.	do.	round shingle, 1 in. diameter.
180 ft.	do.	do.	angular stones as large as an egg.
300 ft.	do.	do.	conglomerate.

One of the most important points in the treatment of rivers is to ascertain their liability to be affected by, and to provide measures against, the destructive results of heavy floods.

The effect of floods is very variable in different rivers, according to local circumstances. It is more destructive when, owing to a retentive soil, to steep slopes on the sides of the valley, or to both in combination, the waters of heavy rains are collected rapidly in the river, so as to swell its volume beyond the capacity of its channel. These effects are modified, on the other hand, by an absorbent soil, or by a flat and extended valley, which retains the water, and obliges it to pass slowly to its natural outfall, thus enabling the discharge to be gradually effected. In this way the flooding of rivers has been aptly described as a race against time; though in the case of long-continued and heavy rains, when the surface and soil become fully saturated, the rainfall begins to flow into the river with almost equal rapidity in the latter as in the former case. But the most rapid and destructive inundations are caused by the melting of snow, and almost all the great rivers of Europe owe their highest floods to this cause.

The absorbent strata in this country are chiefly sand and gravel, chalk, limestone, and sandstone. The extent to which floods, as well as other conditions of a river, are modified by the prevalence of porous strata in its watershed, is well illustrated in the case of the Thames itself. The upper portion of this watershed consists, as is well known, of the chalk formation, which absorbs and stores the rainfall to a large extent, returning it to the river in dry weather by means of perennial springs. In consequence, the stream, excepting in long-continued rains, is uniform to a remarkable degree in the quantity of water it discharges; and its liability to flooding is caused much more by the artificial obstruction of weirs and mill-dams than by any natural condition attaching to the river.

As a rule, a flood commences when the strata, whatever they may be, are saturated with water so that their absorbent qualities are exhausted, and this is frequently exemplified by the circumstance, that a given amount of rain in summer is found to be disposed of by absorption and evaporation, and never reaches the river at all; while the same amount in winter, with a saturated atmosphere and soil, will pass into the river without diminution, and sometimes cause a flood.

The absorbent strata tend to moderate floods, not only in proportion to their porosity or capacity for containing water, but (especially in the case of limestones and sandstones) by the dip of their beds, which, particularly when of steep

inclination, facilitate the subterranean escape of the rainfall.

Again, the effects of a flood are moderated on a large scale in nature by the existence of lakes, which afford an extensive area for the storing or retention of flood-waters, and enable their contents to be discharged gradually and quietly by the outlet rivers at their lower extremities. Many instances of this kind may be referred to. The two great lakes which supply the source of the Nile are said to furnish to the upper portion of that river a remarkably uniform amount of water; and although the river receives directly the flood-waters of the districts below, which convey the well-known mud deposits of Egypt, yet the lakes referred to have the effect, on the whole, of moderating the flooding of the country to a material extent. On the continent of Europe also, the great lakes at the foot of the Alpine ranges, which receive the waters of the melting snows, serve the purpose of moderating the inundations, which, though still often destructive, would render the valleys below those lakes totally uninhabitable if their impetuous discharges were uncontrolled by this provision of nature.

The modification of floods by means of engineering works, is a matter of considerable difficulty. In some cases, as in the Po, dykes or artificial banks have been constructed for this purpose; but the tendency of the river to raise its bed by the deposit of the material carried down by the floods, has involved the necessity of constantly adding to the height of the dykes, until the river is raised above the level of the surrounding country, rendering any future escape of its torrent liable to be doubly destructive.

The French engineers have proposed, for moderating the floods of their great rivers, to form a system of artificial lakes at the mouths of the tributary streams, so that the main stream should not be suddenly surcharged. But the usual and perhaps the most feasible course is to regulate, deepen, and improve the bed of the river itself, and to remove artificial or natural impediments from it, to the utmost practicable extent.

In very many rivers, of which the Thames and Shannon are notable examples, a constant antagonism exists between the interests connected with the navigation and those connected with the drainage of the adjoining country. The former can only be maintained by the construction of weirs or dams, which keep up the water to an artificial height so as to give it depth for navigation, at the same time affording water-power at the overfalls for mills. With the drainage, however, the matter is reversed, as the impediments thus created to the flow of the stream render it impossible to carry off the flood waters with sufficient rapidity from the low-lying lands adjacent to it. It becomes a question, therefore, of the comparative value of the drainage, or of the navigation, to the district. Until the present generation the interests of the navigation have been generally preferred, but the great extension of railways throughout Great Britain has much deteriorated the value, both in a commercial and national sense, of river navigation; and the modern tendency of public policy is to remove all obstructions to the discharge of rivers, as far as it can be reasonably effected with regard to the important private interests which the former policy has created.

It appears, in short, that in the early history of a country rivers play a most important part in providing the means of internal communication; and the Mississippi and other great streams of the American continent readily occur in illustration. As civilization and wealth increase, however, the necessity for drainage is more felt, while superior and more rapid means of communication by railways become universal. The tendency in this case, therefore, is to confine the navigation to the lower portions, where seagoing vessels may be accommodated, and to devote the upper portions to their original purpose of the drainage of the country.

The line of longitudinal section of a river generally forms a concave curve, which, of course, is flat at the lower end and steep in inclination at the source. In the upper portion the water supply is generally limited, owing to the contracted watershed and steep inclination of the bed; but the storm-water for the same reason is delivered into the stream with great rapidity where the strata are composed of retentive soils. Such positions are especially favorable for the working of mills, and are generally so occupied to the utmost possible extent in this country.

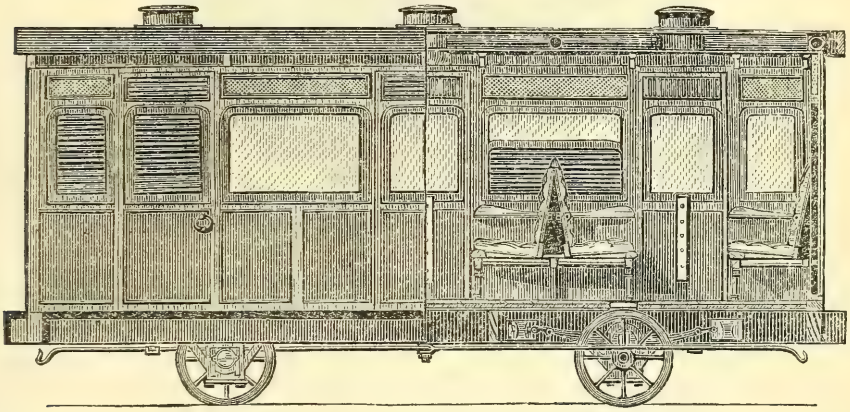
It is pleasing to reflect that at no previous time in our history have the advantages afforded by our British rivers, whether in a commercial, agricultural, or sanitary point of view, been so highly appreciated as at present. The maintenance of their volume is jealously guarded; and the preservation of their purity from all pollution is being made the subject of the most minute scientific investigation and the most careful legislation. In these facts the lovers of nature and of progress may alike rejoice; for in no other natural objects than our flowing streams are the useful and beautiful more fully united.

ROLLING STOCK FOR NARROW GAUGE.

We extract the following from a letter from Mr. Robert Fairlie to "Engineering":

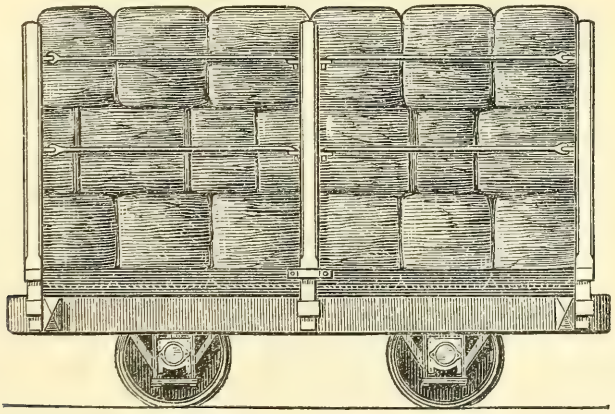
Fig. 1 is a view of a first-class carriage; it is 18 ft. 6 in. long, and 6 ft. 8 in. wide inside, and 6 ft. high, in three compart-

Fig 1.



ments, to seat six persons in each; the division space gives $26\frac{1}{2}$ in. to each passenger; the compartments in length and width are equal to the best modern stock

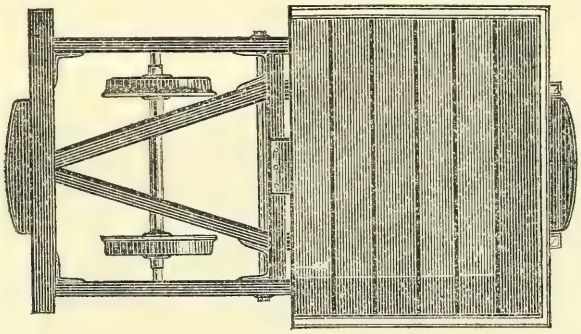
Fig. 2



now running. The carriage complete weighs 3 tons 5 cwt., 1 ton 15 cwt. in the under frame, wheels, springs, etc., and 1 ton 10 cwt. in the body—giving a weight

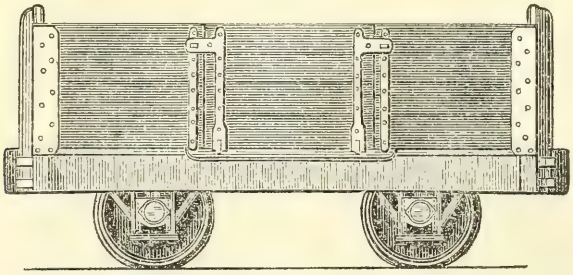
of 3.6 cwt. of carriage to each seat. The second class carriage is nearly similar, except, of course, the interior fittings. It is 16 ft. 6 in. long, and 6 ft. 8 in. wide inside, and 6 ft. high, to seat 8 in each compartment. The carriage complete weighs 3 tons, the under frame, with wheels, axles, and springs, 1 ton 14 cwt., and the body 1 ton 6 cwt., the proportion of carriage weight to passengers being 2.5 cwt. to one passenger. The third-class carriage is similar in size to the second-class, but accommodating five persons on a seat; the proportion of carriage weight to passengers is 2 cwt. to one passenger. The wheel base in the case of the first-class is 9 ft., and in the second only 8 ft. 6 in., so short as to permit the carriage passing a curve of 150 ft. radius with ease, yet it is so long compared to the gauge as to insure a perfectly steady-running vehicle. No buffers are used, but the circular end pieces of rubber faced with a thin steel plate, on my patent principle. The coupling rod is attached to the centre of the carriage frame, from which point it has a

FIG. 3.



radial movement. Fig. 2 represents a wagon to carry cotton in bales, according o the dimensions of the bales usually carried in India. The wagon is a plain, low-sided flat wagon, with six upright posts, having two round iron hinge rods between

FIG. 4.



each, which keep the bales in their place, and stay the posts. The wagon weighs 26 cwt., as follows:

	cwt.	qrs.	lbs.
Oak	5	0	16
Pine	5	2	22
Ironwork	15	0	18
	26	0	0

and carries 4 tons of cotton loaded, as shown; the floor area of the wagon is 6 ft. by 10 ft. 6 in., and carries exactly 24 bales, measuring about 12 cubic ft. each, and weighing 3.75 cwt., giving a proportion of carrying capacity of 3.3 to 1 of dead weight.

Figs. 3 and 4 represent a coal wagon; it is 10 ft. by 6 ft., and 2 ft. $10\frac{1}{2}$ in. high in centre; at ends the cubic space is 160 ft., equal to 4 tons of coal. This wagon weighs:

	cwt.	qrs.	lbs.
Oak	5	0	16
Pine	6	0	27
Ironwork, springs, wheels, axles, etc...	17	1	21
	28	3	8

giving a proportion of a little under 3

tons carrying capacity to 1 of dead weight.

Fig. 5 represents a covered goods wagon; it measures 10 ft. by 6 ft. by 6 ft. high in centre inside, giving a cubic space of 360 ft.

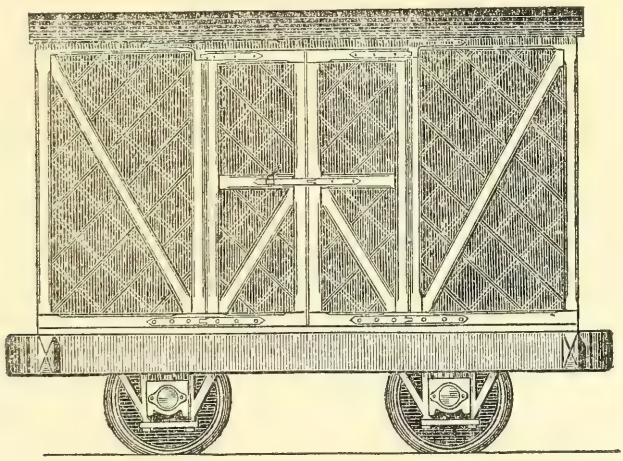
This wagon, of which but few would be required for groceries and special goods, weighs:

	cwt.	qrs.	lbs.
Oak	5	0	16
Yellow pine	12	1	13
Ironwork, springs, wheels, axles, etc.	15	0	27
	32	3	0

giving a proportion of 3 tons carrying capacity to 1 of dead weight, taking the capacity at 72 ft. to represent 1 ton.

The cotton wagons are intended to be covered by sheeting, and in this manner the cotton is perfectly protected, besides being much lighter. This class of wagon is very convenient for loading and unloading compared with covered wagons, and, as it may happen, should cotton take fire by spontaneous combustion, or by a stray spark (which is less likely to set fire to sheet covering than to a dry matchboard covering from the engine), the fact that it has done so is seen at once, and the bale or bales which have been ignited may be

Fig. 5.



tumbled off the wagon without much injury being done; this cannot be done with the covered wagons, the contents of which, when once on fire, may be destroyed before seen, and when perhaps it is too late to save others in the train. When there is no cotton to carry, the posts are removed, and a capital flat wagon is provided capable of carrying the heaviest field artillery, together with all the equipments as now used in modern warfare. The 4-ton cotton wagons have the spaces between the posts at sides and ends fitted with panels of match-boarding, a portable top with six legs can be added, fitting into sockets in the flooring, and a partition is fixed down the centre of the wagon, padded, if necessary, and you have the cotton wagon turned into a first-rate horse-box to carry two horses. The space for each horse would be about 2 ft. 8 in., after allowing for padding, the length of the wagon being 10 ft. 6 in., is ample so far as suitability of gauge for military operations is concerned. You have here a stock that would, on an emergency, move quite as much in the way of military trains as any prepared stock for the purpose on the 5 ft. 6 in. gauge. It is true horse-boxes on the 5 ft. 6 in. gauge will accommodate three horses in them; but, if they do, it is at the expense of weight. A horse-box to carry three horses on the 5 ft. 6 in. gauge will weigh 6 tons, whilst the extemporized horse-box out of the cotton wagon on the 3 ft. gauge would not weigh over 2 tons, with all the additions, and carry 2 horses; so that on the smaller gauge six horses would be carried for the same dead weight as on the 5 ft. 6 in. gauge.

The height of floor from rail is 2 ft. 6 in. There are no platforms required, as there are two steps on each side of the carriage running its whole length as shown.

The angle of stability is 38° both for carriages and laden cotton wagons.

It will be noticed that neither in the carriage nor wagon stock are any buffers used; the circular ends are composed of a block of timber under a cushion of india-rubber, which is faced both back and front with thin steel plates, by Sterne's patent process. The vehicles in each train are all coupled up so as to touch each other, and whether on curves or on the straight, this position is never changed. Each carriage or wagon in a train takes its own true position on the rails without reference to its preceding or following one, the whole being joined together in one continuous mass, but with so many joints, like the vertebræ of a snake. No one wagon need be strong enough to pull the whole train behind it, as is now the case with the ordinary coupling, consequently a large reduction can be made in the framing, and yet be of equal strength. By this system of coupling the accident which cost so many valuable lives at Harrow, a few weeks ago, could not have happened, because the driver of the engine cannot possibly jerk the wagons in his train as he can do now, and break every coupling in it if he chooses to do so.

ON WATER METERS.*

From "Journal of The Society of Arts."

The question of measuring water supply by meter has for a great many years been occupying the attention of engineers. Ever since 1824, a yearly increasing number of inventions bearing upon this important subject, and amounting at the present time to a total of 313, have been brought before the public, in which are included patents taken out in England and communications from foreign engineers which have been registered at the Patent Office; yet, with all this great expenditure of ingenuity, it is generally allowed that there is no meter at present in really practical use which may be considered an accurate, or, in any way, a satisfactory machine.

If we take a review of the time that has elapsed since 1824, when I stated the first patenting of a water meter is on record, we find that up to the year 1851, a period of 27 years, 30 different inventions had found their way into public notice; whilst during the 10 years succeeding, or up to 1861, no less than 90; and again, from 1861 to 1871, or the present time, 193. I do not mean to say that all these were for separate and entirely different machines; the larger proportion were so, but a great many only specify certain improvements in previous inventions, or apply them to particular uses, a process which frequently implies the production of a practically new instrument.

There could be no better argument than the above statistics found in proof of the general demand for a good water meter, since all invention is necessary the result of some extensive public requirement. We may also adduce the fact that, unsatisfactory as are all the meters at present supplied to the public, they have, at least, those amongst them which present fewest defects in working, meet with liberal customers among the water companies and private individuals, who are willing, at much personal inconvenience and expense, to refer the estimate of the supply of water to the arbitration of these meters. In large factories, for instance, or in the case of machinery driven by water or steam power, and large stabling establishments, hotels, and even the better descriptions of dwelling-houses, it has been found an advantageous arrangement, and examples are enumerated by advertisers of water meters, pointing out the benefits likely to accrue to their purchasers, either on one side or other of the meters, from their use. For instance, a sum of £40 per annum paid in one case for water, rose no less than £1,000 in favor of the suppliers, after the introduction of a meter. We may view the matter in another light, by comparing our dealings with water supply with our management of gas, not that the cases are in all respects similar, for gas is a luxury hardly yet a necessity of life, whereas pure, wholesome water is, in the truest sense of the word; but gas is, viewed scientifically, a very similar material to deal with, and is supplied by volume through pipes, and is turned on

* From a paper read before the Society of Arts by Mr. Frederick E. Bodkin.

and off as required, and measured and paid for by meter. Moreover, by comparison of equal volumes, we find that water is the more expensive commodity of the two, which is an additional argument favorable to the use of water-meters under certain conditions, even though there were more difficulty and expense in obtaining them.

If, instead of viewing the extreme cases I referred to above, we consider in a more extensive aspect the question whether the invention and use of a good water-meter would be advantageous to house-holders and other consumers alike, one cannot but feel that the present system adopted for the general public, of payment according to the ratal or means of each separate consumer, is a most wise and liberal arrangement, hanging the chief burden of expense on the wealthier classes, and supplying an equal necessary of life to the lower orders at greatly reduced cost. Nor would the introduction of meters necessarily relieve any particular class, since the same expenditure would have to be defrayed as our requirements of proper purity and supply at present entail on the several water companies, whilst it would certainly act very prejudicially to the appearance and health of the "great unwashed" of our large towns, who would be only too anxious to reduce their water bills to a minimum. Perhaps, however, with the introduction of constant supply, the general use of water-meters might become an advantage—almost a necessity—to prevent waste; but in London, where this would be most severely felt, constant supply is, as yet, only a very remote possibility.

There are also other uses to which water-meters may be applied, such as calculating the supply of water to steam-boilers, for the purpose of ascertaining their evaporative power; also the expensiveness generally of water and steam power, a means of accurately judging which would enable the engineer, with far greater facility, to arrive at their comparative excellences. The great difficulties which surround the designing of a good water-meter must excuse the ill success, so far, of inventors in meeting this demand; these may be better judged of by a short statement of some of the offices required of such a machine.

Firstly, a water-meter should register with accuracy, that is, within 1 per cent. of the truth; and this, it must be remembered, not under a uniform rate of flow of the fluid, but under every possible variation of pressure, from a head of only a few feet, up to 200 or 300, unless indeed it be intended to act as a low-pressure meter, to some of which I shall call attention presently, and also under any ordinary variations of temperature.

Secondly, it ought to be of sufficient strength throughout to stand these high pressures, and even sudden alterations and blows under them, which form a still more trying ordeal.

Thirdly, it is very requisite it should be cheap, both in original cost and to maintain in repair subsequently. This latter consideration is very important, as under high pressures any bearing surfaces would be travelling at a great speed, and, even with the common impurities of water, would be liable to wear away very fast.

Fourthly, simplicity, both in number and shaping of parts, chiefly because all water-meters are liable to get soon clogged with a muddy deposit, and require cleaning, and any complexity renders this operation difficult and expensive; it also naturally infers great costliness in repairs when the machine gets out of order, a defect to which such would be particularly liable.

It also often happens that a meter may be left unused for a time, and the working parts become dry. This should not interfere with the accurate working of the machine on its again coming into use; it is also greatly to the advantage of any meter that it should be uninjured by the entrance of heated water or steam, when supplying steam-boilers or other machinery, where such are used; that it should form a closed valve against the return of water already passed through it; also that the register and work should be out of reach of interference of people desirous to tamper with them; and a very important consideration, that there should be as little loss of head or decrease of flow as possible in the water during its passage through. There are also peculiar excellences, if we may believe the statements of advertisers, which recommend some meters for use in private dwellings, far in preference to others; for instance, a certain Frenchman, with the ardor of competition so peculiar to our neighbors, de-

scribes his invention as not only a perfect meter, but a useful and elegant ornament for a gentleman's hall or drawing-room.

When we come to consider more carefully the leading features of all this vast mass of invention, we find that it is mainly directed to the measurement of water, under two different conditions, low and high pressure; low-pressure where the water is delivered from the meter entirely free from momentum, and high-pressure where the water arrives at, passes through, and leaves the meter at the same, or nearly the same velocity. Low-pressure meters were in use some time before the introduction of the other description, are much more simple in design, and can be made to register with perfect accuracy; but they have now fallen into disuse, except in special cases, where a careful measurement generally of some fluid more valuable than water is required, irrespective of the time occupied in the process. It will be worth while to notice briefly the various ways in which this has been accomplished.

In the most simple method, graduated glass-tubes are used in connection with a barrel, or vat, or closed chamber, and by which the amount of fluid run off can be easily read. Another, almost as simple, consists in the use of a measure-chamber in connection with an ordinary tap; the tap is at one end, and a valve at the other, or feed end of the chamber. These are so connected that one turn of the tap handle allows the water access to the chamber, and closes the outlet; the reverse action closes the inlet valve, and allows the measured quantity to escape for use; each turn of the handle is registered. This principle is applied in many ways, some constructing the measure-chamber large enough for a considerable supply.

A third makes use of a large vessel of known capacity, generally an upright cylinder, and places a valve on a properly fitted seating at the lowest part; there are also floats in the vessel, and while the valve is closed and the water rising, the float also lifts, and in doing so actuates lever arms, which by ordinary mechanism shift the valves when the vessel is full, the lower valve from its seating, and a cut-off valve attached to the inlet pipe. One means whereby this is attained is by hanging a weight from the float over a pulley, fixing a cam on to the shaft of the pulley, and causing the cam to raise a long lever arm at one point of its revolution. As the arm rises and falls, it moves the valve. The float, when out of water, being heavier than the weight, falls with the water and reverses the valves at the bottom; a register tells the number of rises and falls that have taken place.

A fourth group of inventions places two tanks side by side, or subdivides one by a central partition; in each are valves at the lower ends, and each contains a float. In one case a system of siphons is substituted, the supply-pipe is placed over the partition, and alternately made to direct its flow into one or the other subdivision; the floats rise in each alternately, and, in most cases, by a central axis, which they actuate by lever, change the direction of inlet, and raise their own outlet valves; the central axis has weighted arms attached, to insure the instantaneousness of the action.

According to another device, a subdivided trough is centred on trunnions, and caused to tilt or tumble over from one side to the other by the weight of water which has flowed into each division of it from a fixed inlet; the trough is generally made triangular in section, and so proportioned and centred that it shall not tilt until each division is quite full; the number of tumbles is registered in this case.

A further modification of the above arranges a number of these tumbling buckets round a centre spindle, their continual filling and tilting causing the spindle to rotate. Sometimes they are made to work in a water level, each bucket gradually sinking down to it. But when fixed, free to revolve, they are arranged so that each weight of water must overcome the resistance offered by an arm of a weighted lever, which comes in contact with a catch attached to each bucket, and will not allow it to pass until outweighted. The revolutions are registered, and represent in amount so many buckets full each.

A very novel idea is to measure, by means of a gas-meter of ordinary construction, the amount of air exhausted from any closed chamber, from which the liquid is allowed to run, the amount of water extracted being taken as equal to that of the air registered.

Endeavors have been made to convert

several of the above into high-pressure meters, by making them of sufficient strength, and causing them to work without loss of head by air compressed in suitable chambers.

From this brief account it will be readily understood that water can be measured by low-pressure meters with the greatest accuracy, but they are entirely useless for supplying large quantities at any speed. They always require the intervention of a cistern of some considerable capacity placed high up; and in large establishments a separate meter would be required for every cistern. They may, in fact, be considered quite inadequate to the requirements of modern water supply.

Among high-pressure meters a greater variety exists; they may be divided into two principal classes—those which give a positive registration of actual quantities of water, and those which register by inference from the flow or pressure of the water passing through them.

Amongst positive high-pressure meters, various arrangements of piston and cylinder hold the first place. The principle of these meters is, to inclose in a hollow, carefully bored cylinder of known capacity, a piston free to move from end to end by the pressure of the incoming fluid, the piston being caused by this force to drive out the quantities of fluid already measured. This motion, and its degree of perfection, will depend mainly on the arrangement of the valves which regulate the inlet and outlet of the liquid.

In the simplest form, the piston, very carefully packed, is fitted with a long piston-rod, protruding from a packing-box at one end of the cylinder, and bearing one or two catches, which, just as the piston reaches the top or bottom of its stroke, come into contact with or strike against the ends of levers, causing the valves to shift; or the same is effected by a roller on the piston-rod running up and down in a slot in a bar of metal, and striking each end in turn; the bar, on receiving the blow, throws over a weighted lever, which alters the valves; or, by some, a rack is used attached to the top of the piston-rod; this gears with a pinion on a fixed shaft, two catches are fixed on each side of the pinion, and these alternately throw over a weighted lever from side to side; the weight in falling turns a four-way cock. This last is a device used by Mr. Kennedy, in his patent water-meter, one of the first ever brought into use. It possessed the advantages over others of the same time, that it allowed a continuous stream of water to pass without serious loss of head, and registered very correctly. But the acknowledged defects of expense and great complexity, and also the continual attention required to keep it in working order, have caused its gradual fall into disuse, for it was found, as soon as the oil in the works, which are not in these meters in contact with the water, got thick, the tumbling-weight refused to fall, and the water passed through the half-open valve without registry; and fresh oiling was found necessary every few months.

Messrs. Chadwick and Frost, in their Manchester positive meter, cut a long flat strip off one side of the upper part of the piston-rod; against this flattened portion a roller is pressed to the end of a bent lever, the square ends of the strip or slot drive the other end of the lever at right angles to the piston-rod, causing it to actuate in that line of direction a valve, which allows the water to flow alternately through the connecting link to the back of two small circular discs; its pressure at once forces each forward in turn, carrying the main valve with it, thus forming a fluid pressure valve. This arrangement is found superior to Kennedy's meter, and in fact has gained the ascendency over all other cylinder meters we possess; but it is an expensive meter, and the number of wearing surfaces it contains prevent that durability which a high original expenditure ought to insure to customers. It will not either, without great additional outlay, stand exposure to heated water.

A French patentee specifies a long cylinder, containing two pistons joined by a rod, passing through a central division with bearings, on which the cylinder rocks, by the greater weight of fluid alternately in each end, the central bearing being hollow and arranged on the four-way cock principle, and opened and closed by the tilting of the cylinder.

A large number of meters have also been devised, with two or more cylinders as measuring vessels; these are fixed side by side, fitted with pistons, and their rods working a common shaft by means of cranks. By the revolution of this shaft,

two eccentrics or cams are made to open and close the valves ; these are sometimes placed between the cylinders, sometimes on the outside, and in one case, in a meter designed by Mr. Duncan, placed at considerable angle to the piston-rod. When the cylinders are placed in the same line, end to end, as in the case in some meters, the rod connecting the two pistons, by means of a long catch, is made to actuate bars placed parallel to the piston-rod and outside the cylinders. These bars move secondary valves, the primary valves being p'aced at right angles across the further ends of the cylinders, and driven by water pressure regulated by the secondary valves, thus forming a similar, but more clumsy, fluid pressure valve to that used by Messrs. Chadwick and Frost. In some cases the cylinders are made so as to slide telescopically on one common cylinder open at each end, with a central water-tight division ; but in this arrangement the valves are a great difficulty, and the accurate fitting of the cylinders is expensive.

When the cylinders are set at an angle to one another, it is generally, as in an invention of Mr. Jopling's, at right angles, and the piston-rod of one is made by direct action to open and close the valves of the other, the pair being enclosed in a water-tight casing.

An invention of Mr. Worthington's, of the United States, consists in an arrangement of two cylinders, each containing two plungers or pistons connected by a single rod, bearing a central division plate. The valves are placed between the containing cylinders, and the alternate spaces are connected by crossway passages, from one into the other of which the water flows before it leaves the meter.

The chief object aimed at by the combination of several cylinders is a continuous discharge from the meter, and the prevention of any concussion occurring in the pipes. This is so perfectly effected by Messrs Chadwick's meter, that any additional complication and expense, such as these machines involve, is quite needless.

Another American method uses a cork pis on or ram, packed with cupped leathers; and a Mr. Heppel furnishes a solid wooden cylinder, with an annular leather bag, and causes it to work loosely in a cylindrical casing. These have their advantages in cheapness and absence of friction, but their adaptability in continual contact with water is very questionable. The best form of piston for a water meter appears to be a cylinder of metal with a flange at each end, the intervening space being long enough to allow the travel of a rolling ring of india-rubber up and down during each stroke of the piston.

There is yet another combination of pistons and cylinders which has been devised for measuring water. The inventor places a number of cylinders round a central shaft free to revolve, and attaches the heads of their piston rods to the corners of an inclined plate centred on the central shaft; the pressure of the water against their pistons causes them to rotate, and their revolutions open and close their respective valves. They may also be placed along a common trough or pipe, and their piston-rods in gear with a common crank shaft. They are free to oscillate, and, in doing so, valves at their junction with the main pipe are alternately open to each side of a central partition in it, which divides outlet from inlet.

The next description of positive meters includes all which are constructed to work with flexible or elastic diaphragms. The principle of these meters is, that a perfectly water-tight partition shall be formed, capable of assimilating itself to either end of a containing chamber, its edges being firmly bedded in the sides of the chamber, so that water admitted on either side alternately will force the diaphragm tight against the other. The shape of the chambers used to enclose these diaphragms is generally those of a double sector, or a sphere, or with inclined sides and flat ends. The chambers are most usually broad and shallow, and made of two shaped plates bolted firmly together, with the diaphragm between them. This is made of leather or vulcanized india-rubber, toughened by layers of calico or prepared cloth. It is generally strengthened by a central plate of metal, to which a piston-rod is attached, which passes out of the chamber and actuates the valves.

In one patented by Mr. Ramsbottom, in 1855, there are two diaphragms in doubly conical chambers, the rods of which turn a common crank shaft. On this are two mitre wheels, which turn a rotary valve between them.

In a German meter, the rod actuates a lever with a chordal rack attached to the further end. This gears with a pinion, a crank on whose shaft moves the valves.

In another meter, four diaphragms are used at right angles, and all driving the same central shaft by means of cranks. From this shaft the registry is taken, and it is made to distribute through valves the supply of water to each pair in turn.

Meters of these descriptions will work with great accuracy, whilst the diaphragm remains entire. But it has been found impossible to discover any material which will endure active work with certainty; and, as soon as the smallest flaw occurs, water passes without registry.

Closely allied to meters of this description, are those whose measuring chambers are made of compressible bags or cylinders. One of the simpler forms of these was patented in 1850. It consists of a water-tight chamber, containing two compressible cylinders, distended with metal rings at intervals. Their upper ends rise and fall vertically as they fill and empty, raising and lowering each end of a bar with them. Chains from these ends pass over separate pulleys, and are attached to the ends of a cross handle of a four way cock. Another design fastens two such cylinders end to end on a rocking arm passing right through them. They rise and fall as they alternately increase and lose weight, and alter valves seated at their point of connection.

Compressible tubes have also been often suggested as water-meters; for use as such, they are wrapped round a centre cylindrical core, or coiled in a ring on a circular plate, and a pair or more of rollers, revolving round a shaft placed in the centre of the bag, and pressing tight against it, are caused to move by the pressure of the water entering one end of the bag, and forcing the rollers before it, in order to escape at the other extremity. By the time one roller has arrived at the end of the bag, a second comes into play; thus a series of waves of equal and known amount are continually passing through the bag, and being registered by the central shaft. An invention of Mr. Siemens makes use of a similar principle, by causing waves of liquid to pass down a tube of rectangular section, between the sides and a flexible central division. To all such meters the same objection holds as in the case of the diaphragm meter—that they are most uncertain in duration, especially if liable to stand idle, and their flexible portions to get dry and hard.

An entirely different description of meter are those which work on the principle of rotary force pumps or fans. They are usually made with cylinders or axes revolving either in the same centre or eccentrically in outer cylindrical casings with closed ends. The simplest form is that of a plate sliding in a hollow cylindrical shaft or an elliptical disc, sliding on a crank and revolving in an epicycloidal chamber, the inlet on one side, the outlet on the other. The fluid continues to flow and the ends of the plate or disc cut off equal quantities of fluid, and register the number of revolutions. Or the centre cylinder may be concentric with the outer casing, and have one or more flat vanes of metal let into slots in its periphery, which are forced into it at a certain part of its revolution, between the inlet and outlet holes, by a bulge or indent in the outer shell, causing the periphery of the inner cylinder to revolve in close contact with it, and forcing out the water included between any two of the vanes. These vanes are carefully packed and must revolve in close contact with the outer circle, and for the purpose of always keeping them tight against this, a cam is placed inside the inner hollow cylinder, which forces them out at all parts sufficiently,

A French invention proposes to shut up air in the inner cylinder, and trusts to its compression and expansion to keep them in gear.

According to another, an eccentric axle is fixed inside the inner cylinder with four short arms; on to these are hinged the travelling vanes, which at a certain part of the revolution, where required, bend at the hinges and recede, and afterwards again straighten and are forced forwards.

In these machines the accurate fitting and easy travel of the vanes is of great importance; but however carefully this may be carried out originally, from constant use these machines soon give signs of wearing, and neglect to register accurately.

Some inventors make use of oscillating vanes or pistons swinging round in hollow cylinders from one side to the other of a fixed partition, the inlet and outlet

being on each side and reversible by valves; and even more complicated arrangements of two or more swinging vanes, sometimes in adjoining cylinders, and other equally impracticable machines, have been proposed.

A great many adopt the method of hinged vanes or floats, capable of laying close alongside their centre spindle, and of spreading out against the encasing cylinder under pressure of water. After the principle of the fan, the vanes are made concave against the pressure of the water, and are hinged on to a cylinder, so made to revolve eccentrically, that just before it reaches the inlet opening, the blades are folded closely down, but on passing it they spread, and do not again close until they have passed the outlet.

Different arrangements of two cogged wheels, rolling in contact, have also been suggested; they are made of considerable breadth, and are placed in a double cylindrical casing, the one riding loose, the other fixed on a shaft which actuates the register. The teeth of such wheels must be very carefully made, in order to continue in contact at every instant of their revolution, the water being usually supplied immediately under the point of contact. It will be easily understood that the efficiency of the machine depends entirely on the good fitting of the gearing surfaces of the wheels, and which equally applies to the preceding description of meters, to the careful packing at each end of the drums. A meter which has not come into public use, but which has been found to work satisfactorily, when applied to measure the water supplied to steam boilers, consists of a string of ball fitting accurately in a loop formed in the supplying-pipe, and, passing over a pulley at each end, the water enters on one side of one pulley, and, carrying the string of balls before it, passes out at the other extremity. These balls cause the pulleys to revolve, and show how much water has passed.

Amongst inferential meters, which depend for their accuracy on their estimate of the velocity of the water passing through them, those which register the revolutions of an annular ring of metal, fitted with floats or paddles round its periphery, are most numerous; the water in this case being admitted through apertures, as nearly as possible at right angles to the surface of the floats, impinges against them and causes revolution in a very irregular proportion to the speed and pressure of the water. An invention of Mr. Ramsbottom's has been used to some extent, and consists of a wheel with radial floats. Another machine, by Mr. Taylor, is very similar. He uses a horizontal wheel, provided round the periphery with radial floats, and riding on a vertical spindle in a closed chamber. It is to be made of any material of the same specific gravity as water, in order to reduce friction on the bearings, and is driven by the water admitted through small holes close to the wheel. This meter has been used considerably in the North of England, but is found much inferior in correctness and power of discharge to others.

To insure an even flow, which was the only condition under which these meters would work accurately, and to prevent low pressure water from passing at all, several different methods have been devised. By one arrangement, the water is required to raise a clack-valve, held down to its seat by a delicate spring, before it can impinge against the drum; by another, the water is caused to pass through a contracted elastic orifice; and by a third means, the flow of water in its action on the drum is regulated by a specially designed governor.

The next class of inference meters include all those which register the rotations of drums with screw blades fixed round them. These drums are fitted into long cylindrical casings, and the water flows past them, having been first directed through fixed guides turning in the opposite direction, and causing it to impinge on the drum-blades at nearly right angles. An earlier invention of Mr. Siemens is of this description, who uses two drums, or two pairs of drums, turning in opposite directions, and set end to end in the same tube. The drums are made hollow, of a peculiar alloy, and have eight perfect screw threads passed round each. The registration is taken off the central ends of the drum shaft by means of mitre wheels, and there are directing guides equal in number, but exactly opposite in direction between each.

A patentee of 1851 places a similar drum, but rather longer, on a valve seating in a vertical pipe; it is thus rendered

capable of lifting before any impurity which may be carried along with the water. Some others use a great many series of drums and guides, and occasionally choose to admit the water without guides simply between two reversed drums on the same spindle. The accuracy of these machines depends largely on the careful fitting and balancing of the drums, and their continuing to work without friction; but even under the most favorable circumstances, they will not register with sufficient correctness at varying pressures, the error generally tending towards insufficiency at low pressures, and rising above the real amount at moderately high ones.

A further improvement has been suggested and used by Mr. Siemens and others, on the principle of a Barker's mill, whereby the water is admitted into the interior of a chamber fixed on a spindle, out of which it flows by means of bent or curved hollow arms; the reaction of the outflowing liquid (for the vessel is entirely under water) causes it to rotate in an opposite direction; the spindle moves on a steel pivot encased in a water-tight oil-chamber; the water is admitted through a dirt-box; the revolving chamber is furnished with retarding vanes, and the upper end of the shaft has a worm-wheel attached, which works the register.

The above metre has found most favor before the public, both in England and abroad, of all the metres yet introduced; but notwithstanding its superiority, it possesses many defects. It is expensive, and is not by any means certainly correct under all pressures; it is, besides, so very delicate, that it continually requires inspection and repair. It will pass water through at low pressures with a very insufficient registry, and will work backwards without difficulty.

A great step in the removal of all the above defects, both in this and every other meter yet introduced, is exemplified in an invention by Messrs. Cook and Watson, a metre which has only lately come before the public notice. It consists of an upper plate, indented on the under side with a ring of thumb holes, and riding loosely in a chamber over a lower plate, through which inclined inlet holes are bored. The water rises through these holes, raises the upper disc, and acting against the square ends of the thumb-holes, causes it to rotate at the same time. This action of course requires some small power to commence, but as soon as the upper plate is lifted it must also necessarily rotate. When the supply ceases the upper plate falls, and forms a tight valve against the return of the water; and since during its period of revolution this plate floats in a film of incoming water, there are no wearing surfaces involved in the machine. Small stays are placed on the upper surface of the revolving plate, in order to produce regularity of motion under varying pressures, and appear, from the specimens I have at different times been enabled to test, to do so with complete success.

These machines are not expensive, and offer but small opposition to the flow of the liquid, and certainly appear to be the simplest and most practicable form of high pressure meter yet invented.

A very different description of inferential meter consists in the use of a rod of alabaster, or other slowly soluble material, encased in a glass rod graduated, and at its lower end in contact with the running water. It is kept pressed down, and as it dissolves, the top descends and is supposed to denote the quantity of water which has passed. This seems very simple, but the readings must often be liable to considerable variation.

Russian Railways.—It is stated from St. Petersburg that the Russian Government proposes to concede 6,000 versts of new railways. In the course of the current year these concessions will be granted to the extent of 2,000 versts, either to companies or to private individuals. This is all very well, but Russia cannot be warlike and industrial at the same time; if she is warlike, she will not collect much foreign capital to assist her in the construction of railways.

Mints in Nevada.—The branch mint at Carson City, Nevada, is already a success. Not quite a year in existence, it does quite a large and increasing business in coining and refining.

The late reports from the Suez Canal encourage hopes of its financial success.

LIMES AND CEMENTS.*

From "The Building News."

Mr. Hunt commenced his paper by a reference to the causes which act in giving some limes the power of setting under water. He observed that Smeaton, when engaged in the construction of the Eddystone lighthouse, found that all limes that set under water were obtained from the calcination of limestones which contained a portion of clay in their composition, and his experiments led him to use a cement composed of Aberthaw lime and of Pozzolano. That Smeaton was right in the selection of his stones was almost certain, though perhaps he did not quite recognize the important part which the presence of clay (or silica and alumina in chemical combination) had in the result which he obtained. Referring to some tables exhibited on the walls, containing analyses of the best hydraulic limes, Mr. Hunt observed that such limes almost all possessed the same bodies, though in varied proportions. Limestones or calcareous stones (or those stones containing carbonate of lime) are of very various natures. There are, for instance, pure carbonates of lime (some of which are perfectly crystalline, as marbles), and others which contain, in addition to the carbonate of lime, magnesia, oxide of iron, manganese, silica, and alumina. The name limestone is generally applied to those stones containing at least 50 per cent. of carbonate of lime. A mere chemical analysis of a sample does not always give the results that are obtained by practice. Experience alone is the best guide in this matter. The existence of carbonate of lime in stones is easily detected by the application of dilute nitric or muriatic acid ; by the effervescence which takes place, caused by the escape of the carbonic acid gas from the carbonate of lime, pure lime is left behind. The next most important substance which enters into the composition of limestones is silica, which exists very nearly in a state of purity in flints, common quartz, agate, etc. It is not sensibly soluble in water or dilute acid, but dissolves freely in alkaline solutions at a temperature of from 300 deg. to 400 deg. Fahr. The next and last substance that plays any important part in limestones is alumina, which is recognizable in the form of common clay, but not then in a pure state, but in chemical combination with silica. None of the other bodies, except magnesia, are of any value as regards the hydraulicity of the lime. Chemical analysis shows that the stones which contain only from 1 to 6 per cent. of silica, alumina, magnesia, iron, etc., either separately or in combination, give rich limes upon being burnt. Limestones containing insoluble silica in the shape of sand, magnesia, oxides of iron, and manganese, but limited to between 15 and 30 per cent. of the whole mass, yield poor limes. Limestones containing silica in combination with alumina, magnesia, and traces of oxide of iron and manganese in various respective proportions, but within the limits of from 8 to 12 per cent. of the whole mass, yield moderately hydraulic limes. When the foregoing ingredients are present in the proportion of from 15 to 18 per cent., but the silica in its soluble form, the limestones yield an hydraulic lime. When the limestone contains more than 20 and up to 30 per cent. of these ingredients, an eminently hydraulic lime is yielded. Limes owe their hydraulicity to the presence of a certain quantity of clay, and sometimes, though rarely, to that of a certain quantity of soluble silica. It is supposed that during the calcination, silicates of lime and alumina are formed, with an excess of lime ; these, in slaking, absorb a quantity of water, and solidify in combining therewith, and the double salt being insoluble in water, the compound remains therein without decomposing, or at least only yields that small excess of lime which might have existed in the combination. Rich limes are the purest limes we possess, and the purer the carbonate of lime from which they are obtained, the more distinct are the appearances from which they take their name. These are, that they augment in volume to twice their original bulk (or more) when slaked in the usual manner. If employed by themselves without any admixture of foreign substances, their consistency is the same after many years of immersion as on the first day. Poor

* From a paper read by Mr. H. E. Hunt before the Civil and Mechanical Engineers Society.

limes do not augment in bulk at all, or only do so to a very trifling extent when slaked. They do not harden under water more than rich limes, and are acted upon by that agent in nearly the same manner. The middlingly-hydraulic limes set under water after from 15 to 20 days' immersion, and continue to harden for some time afterwards, but the progress of their hardening diminishes after the sixth or eighth month; after a year their consistence is equal to that of dry soap. The change of bulk they undergo in slaking is about the same as that of the poor limes. Hydraulic limes set after from six to eight days' immersion, and continue to harden; the process of solidification may extend over twelve months, although the greater part is completed by the end of the first six. Eminently hydraulic limes set within the third or fourth day of their immersion. After a month they are quite hard, and capable of resisting the dissolvent action of running water. No limestones are capable of producing, in a commercially valuable form, hydraulic limes unless silica be present in combination with alumina. All experiments go to show that, in proportions cited, it is the most efficient agent in producing the hydraulicity. Mr. Hunt next proceeded to speak of the calcination of limes, after which he enumerated and described some of the best known hydraulic limes of the country. Firstly, he named the Aberthaw lime, the chemical analysis of which is as follows: Carbonate of lime, 72.91; alumina, 7.18; silica, 10.74; oxide of iron, 1.77; moisture, etc., 7.40 = 100.00. The best proportions for hydraulic mortar are from 2 to 3 parts of sharp sand to 1 of lime. If the lime be used for concrete, 6 parts of shingle, or even more, may be used. When the lime is used for concrete under water, it should be mixed up for some hours prior to its being placed in the foundations. It usually requires a day to be set under water. This lime was used by Smeaton for the Eddystone lighthouse. The price, delivered in London, is 22s. 6d. per ton. Another powerful hydraulic lime is that made from the Halkin Mountain limestone, and which was exclusively used by Jesse Hartley, in the construction of the Liverpool docks. The analysis of this limestone is: Silica, 21.56; carbonate of magnesia, 80; alumina, 1.16; oxide of iron, .50; carbonate of lime, 72.60; water, etc., 3.38 = 100.00. This lime has very great power of setting under water. In rubble masonry and backing up for dock walls, the proportions are: 1 part of lime, 2 of sand, and $\frac{1}{4}$ of smithy ashes, ground for twenty minutes. The best mortar for foundations, sewer bottoms, pointing, etc, is made up of 1 part of lime, $\frac{3}{4}$ of sand, and $\frac{1}{4}$ of ashes, ground forty minutes. The most extensively used hydraulic lime of all, however, is the blue lias. Its chemical analysis is: Lime, 45.50; alumina and silica, 18.50; carbonic acid, 31.50; water, 4.5 = 100.00. The best quality in this large bed is to be obtained from the quarries in Warwick. The best proportions of lime to gravel, for concrete, are 6 to 1 if the gravel is good, and in ordinary weather; for mortar, 2 or $2\frac{1}{2}$ to 1. The mortar is not of itself sufficiently hydraulic to set under water, but if allowed to remain for 24 hours, the water has no effect upon it whatever.

In the discussion which followed the reading of Mr. Hunt's paper,

Mr. C. H. Whitaker, who had conducted a large series of Government experiments for Mr. Grant, exhibited some very interesting tabular diagrams, and gave to the meeting an explanation of the objects sought to be attained in each experiment, and the mode of conducting them, with the deductions he had arrived at from the results obtained. Mr. Whitaker said that Mr. Grant's tables (published in the "Minutes of the Proceedings of the Institution of Civil Engineers") showed that the tests of strength of neat cement and of cement and sand proceeded very regularly and in the same increasing ratio from one day to one year or more. At from one to two years, Portland cement appeared to attain its maximum strength, at which it continued to remain without either increase or diminution. Portland cement gauged in a mortar-mill for half an hour with the expectation of a higher result than from ordinary hand-gauging (on account of the more probable intimacy of the mixture of the cement and water) showed the cement, however, to set hard, but very brittle, the highest test being less than half that of the same cement gauged at the same time by hand. Mr. Whitaker suggested to Portland cement manufacturers whether it would not be possible

to make cement of two different qualities — the one such as we know, hard, and capable of great sustained pressure, like cast-iron for instance ; the other not, perhaps, capable of bearing so high a test of the ordinary kind as the first, but, being of a somewhat elastic nature, able to sustain a sudden blow (as wrought-iron), such as the impact of a wave; and, further, whether it was not probable that cement of this kind (though according to the present system of testing not so good) would be better suited to marine works, breakwaters, and similar structures. With regard to the adhesive power of different kinds of bricks with cement, those bricks whose porosity was the greatest, were (as might be imagined), as a general rule, found to hold the cement best. Stock bricks, undoubtedly, had the greatest power of adhesion to cement, but being more friable, broke at a point lower than that arrived at with some of the denser bricks, such as the Suffolks, Fareham reds, etc.; one brick of either of each sort would readily absorb 1 lb. of water. In each of these cases it was the brick itself which most often gave way, particularly the stocks. But as it was the *bricks* and not the *joints* which were broken and registered when this kind of fracture occurred, the relative adhesive value of each was not obtained, though it appeared to him most probable and most reasonable that the stocks would stand highest. There was no better brick for making sound work, especially in water-work, underground, or in damp situations. The experiments he had conducted tended to show that the stock-bricks bedded in cement set 18 per cent. stronger in water than in air, whilst all the other kinds, except some of the Galt bricks, set better in air than in water. He was not able to give the meeting any information as to the setting of *limes in water ;* but a mortar composed of one part of blue lias or Dorking lime, and two parts of sand, seemed to be of about an equal strength with Portland cement compo, made in the proportion of 3 to 1. With regard to different kinds of Portland cement concrete, various materials had been tried, as broken glass, flints, pottery, Portland stone, and granite, as well as ordinary river ballast. The blocks were made of two different sizes, viz., 12 in. cubes, and 6 in. cubes, one set of each being kept in water, and another set in air for one year, when they were tested by crushing in a hydraulic press. The Portland stone concrete gave uniformly the highest results, that made in the proportion of 6 to 1, breaking at a pressure of nearly 1 ton per sq. in. The sharp angular pottery and broken flints were the next highest in the scale. The granite did not come out so well, and the ballast showed the lowest breaking strain of all, giving an average test (at 6 to 1) of about 0.60 ton per sq. in. The broken Portland stone appeared to be completely incorporated with the Portland cement, the whole becoming one homogeneous mass, the stones not tearing away from the cement when broken, but the entire block crushing together through stones and cement alike. The rough biscuit-like edges of the broken pottery gave to that material a similar character to the Portland stone, though in a less degree, and the sharp angularities of the flints, with their rough calcareous portions, gave to the concrete made with them the strength it was found to possess. The granite concrete appeared to have a tendency to crumble somewhat, and the round pebbly nature of the ballast giving the cement less hold on the particles of stone seemed to be the cause of its sustaining a less load than the other concretes experimented upon. Of a large number of tests of ballast concrete (being that most generally used), the strength varied most uniformly, according to the proportion of cement employed. One interesting fact which came out was that the larger cubes (12 in.) set in water stood a greater weight than those set in air, but the small blocks (6 in.) were stronger set in air than in water. It was suggested that concrete made dense by compression would stand a greater pressure than that made in the ordinary way. With this view duplicate sets were made similar to the others in every respect, with the exception that the materials were rammed into the moulds by hand-beating with a mallet, getting thereby more material into a cubic foot than when only thrown in and left to settle in the ordinary manner. The result showed that these blocks formed by compression broke at an average of 30 per cent. greater strain than ordinary concrete, leading one to infer that, could a still

greater pressure be applied, and greater density thereby obtained, a still higher result would follow. Mr. Whitaker said that Portland cement was undoubtedly the best for joints in any case, but that in tide-work, or where only a short time elapsed between the bedding of the bricks or stones employed, it was a good plan to strike the Portland cement joints as usual, and then point them on their extreme outside with a thin layer of Roman cement, which, setting immediately, would protect the Portland cement joint until it was completely set and needed no further aid from the Roman cement, which might wash off at leisure.

THE RESISTANCE OF FLUIDS.

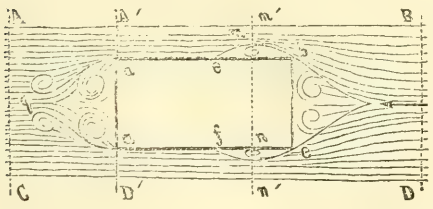
Translated from "Sonnet's Dictionnaire des Mathematiques Appliquées."

The resistance of fluids, except in a few cases, which will be considered hereafter, may be assumed as the same, for a body in motion in a fluid at rest, or for a body at rest in a fluid in motion, or for a body moving in a moving fluid.

THE RESISTANCE OF WATER.

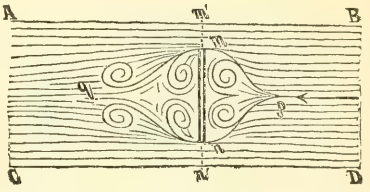
I. Let us first suppose that this acts upon a body entirely submerged in water. A striking complexity of motions is observed in the movement of water acting upon a solid body at rest, as shown by colored particles of dust suspended in the fluid. Let a plane, *mn*, rest in a fluid moving uniformly in the direction of the arrow (Fig. 1). The liquid molecules separate at some distance in front of the plane, diverge, and move in a lateral di-

Fig. 1.



rection; after passing the plane they converge, and finally resume their original parallelism. At the same time, in a certain space, *mpn*, in front of the plane, and in a space, *mqn*, behind it, there are fluid molecules which are affected only by gyratory motions. Similar movements are observed beyond the space *mqn*, caused by molecules flowing from *mm'* and *nn'*, to fill the wider space, AC. If the body is of the form of prism, or a cylinder (Fig. 2), *abcd*, being a section through the axis, the liquid particles, as in the first example, begin to separate at a certain distance in front of the body, and continue to diverge beyond the anterior face, *bc*, until they have reached a section, *mm' nn'*, where they become parallel, then they converge towards the sides of the body, and run parallel to it as far as

Fig. 2.



the posterior face *ad*; here they converge, and at a certain distance beyond *ad*, they resume their parallel motion. In all the intervals, *bpc*, *bme*, *cnf*, *aqd*, there are particles having gyratory movements. The same phenomena occur when a solid body moves in a fluid at rest.

If the body has a rounded end, such spaces as *mpn* (Fig. 1), or *bpc* (Fig. 2), which contain the gyratory particles, become smaller, and even disappear, if the form admits. This holds for either end. If the body is simply prismatic or cylindric, the spaces *mpn* or *bpc* form a kind of liquid *bow*, which accompanies the body in its motion, while *mqn* and *aqd* form a liquid *stern*. The circumstances described hold for all sections along the axis; for vertical as well as horizontal sections.

The complication of these phenomena forbids us to expect that they can ever be submitted to a rigorous analysis, so that an exact expression for the resistance can be obtained. But attempts have often been made to obtain an approximate expression for this resistance. Newton, in his "Principia," has given two theories, one of which, adopted by most authors, is a follows: Let *m* be a body

having a uniform motion of translation, with the velocity V in a fluid at rest; let m' be its position at the end of the time, t. Each point of the body will have passed through a space Vt, and the body will have generated a volume equal to that of the circumscribed cylinder, whose length is Vt. If A is the area of a right section, this volume is AVt The body has, therefore, displaced a collection of models of volume, AVt, imparting to them a velocity V. The total living force of the displaced molecules is:

$$\tfrac{1}{2}\,\frac{W\,A\,V\,t}{g}\,V^2,$$

W being the weight of a cubic metre of the fluid. The molecules must have received a pressure where work is equivalent to that of the living force. If R is this pressure its work is R. Vt; we have then

$$R\,.\,V\,t=\tfrac{1}{2}\,\frac{W\,A\,V\,t}{g}\,.\,V^2,$$

$$\therefore R=W\,A\,.\,\frac{V^2}{2\,g}.$$

This measure is evidently that of the equal and opposed resistance which the body has received from the liquid. It is equivalent to the weight of a cylinder of liquid having for base the section of the circumscribed cylinder, and for height, the height due to the velocity.

II. Modern authors have attempted to determine the resistance by more profound investigations. Mr. Belanger has treated in a complete manner the case of a cylindrical body placed in the interior of a pipe, supposing the length of the cylinder to be at least three times its diameter. Let S be the transverse section of the pipe A B C D (Fig. 2),

A, the right section of the cylinder $a\,b\,c\,d$.
V, the velocity of the current in A C and B D.
V', the velocity in the annular section $m\,m'$, $n\,n'$, which we designate by S'.
V'', the velocity in the annular section a A', d D' which designate by S''.
P_1, P_2, P', P'', the pressures per meter in the sections B D, A C, S' and S''.
R, the resistance opposed by the cylinder to the motion of the liquid.

The motion being permanent, consider the portion of the fluid comprised between the sections B D and A C. The total quantity of motion remains constant, and consequently the sum of the total impulsions of the forces applied to it is zero.

Hence

$$R+P_2\,S-P_1\,S=0$$
$$\therefore R=S\,(P_1-P_2) \qquad (1.)$$

Considering the portion of fluid comprised between the sections B D and S'; as the fluid experiences no sudden variation, we have by Bernouilli's theorem,

$$\frac{P_1}{W}-\frac{P'}{W}=\frac{V'^2}{2\,g}-\frac{V^2}{2\,g} \qquad (2.)$$

Passing from the section S' to the section S'' the fluid experiences a sudden enlargement, and Bernouilli's theorem is modified. We must add to the second member the height due to the difference of velocities; giving

$$\frac{P'}{W}-\frac{P''}{W}=\frac{V''^2}{2\,g}-\frac{V'^2}{2\,g}+\frac{(V'-V'')^2}{2\,g} \qquad (3.)$$

From section S'' to section A C for like reasons,

$$\frac{P''}{W}-\frac{P_2}{W}=\frac{V^2}{2\,g}=\frac{V''^2}{2\,g}+\frac{(V''-V)^2}{2\,g} \qquad (4.)$$

Adding member to member (2), (3), and (4),

$$\frac{P_1}{W}-\frac{P_2}{W}=\frac{(V'-V'')^2}{2\,g}+\frac{(V''-V)^2}{2\,g} \qquad (5.)$$

and substituting in (1)

$$R=W\,S.\left[\frac{(V'-V'')^2}{2\,g}+\frac{(V''-V)^2}{2\,g}\right]$$

But, on account of the incompressibility of the liquid, we have the relations

$$S\,V=S'\,V=S''\,V$$

or

$$S\,V=m\,(S-A)\,V'=(S-A)\,V'' \qquad (6.)$$

m being the coefficient of contraction relative to the diminution of the section of the liquid in passing from bb', cc', to mm', nn'. Substituting the values V' and V'' determined by these relations, we have

$$R=W\,S\,\frac{V^2}{2\,g}\left[S^2\,.\,\frac{\left(\frac{1}{m}-1\right)^2}{(S-A)^2}+\frac{S^2}{(S-A)^2}\right]$$

or putting $S=A\,n$

$$R=W\,A\,\frac{V^2}{2\,g}\,.\,\frac{n}{(n-1)^2}\left[n^2\left(\frac{1}{m}-1\right)^2+1\right]$$

an expression which is of the form

$$R=k\,W\,A\,.\,\frac{V^2}{2\,g}$$

which is of the same form as the formula given by elevation.

M. Belanger has obtained analogous formulas by considering the case of a small disc, or a disc with a rounded prow. Mr. Poncelet, in a memoir at the close of his "Introduction a la Mecanique Industrielle," has arrived at the same results

by applying directly the principle of mechanical work; and he has extended these results to the case in which the body moves in a medium of indefinite extent, hypothesis that in this case the influence of the movement of the body extends only to a certain distance, and that it may therefore be regarded as placed in a canal limited in the transverse direction. The considerations in the case of a conduit then become applicable.

These diverse theoretical investigations lead to the conclusion that the resistance opposed by a fluid to the relative motion of a body is in all cases proportional to the square of the relative velocity. Most authors since Newton have admitted this.

When the velocity is oblique to a plane surface, it is admitted that the resistance is proportional to the square of the normal component of this velocity, so that if i denotes the inclination, the resistance is

$$R = k \,.\, WA \,.\, \frac{V^2 \operatorname{Sin}^2 i}{2g};$$

that is, it is proportional to the density of the fluid to the area of the surface impinged upon, and to the square of the sine of the inclination.

But this law holds only when the length of the body is inconsiderable with reference to the transverse dimensions. For as the length increases, it becomes necessary to take into account the lateral friction along the sides. Coulomb was the first to show that the formula for this friction should contain two terms, one proportional to the square of the velocity and expressing the loss of living force due to the concussion of the liquid molecules against the roughness of the sides, the other proportional to the velocity simply, and representing the effect of the cohesion overcome. M. de Prony, Eytelevein and others have adopted this view. The expression for the resistance should be increased by two terms proportional to the lateral wetted surface, which we indicate by S, and it is of the form W S $(aV + bV_2)$. By assigning to a and b the proper values the friction in front and behind may be taken into account. The total resistance is

$$R = k\,W\,A\,\frac{V^2}{2g} + W\,S\,(aV + bV^2) \qquad (B.)$$

III. A great number of writers have made experiments upon the resistance of fluids. Without speaking of Galileo, who was the first investigator, we may mention the experiments of Newton and Désaguliers, those of Borda, Hutton, Bossut, d'Alembert, Condorcet, Dubuat, Coulomb, Col. Beaufoy, Piobert, Morin, Didion, Col. Duchemin, and Thibault; and concerning the resistance of keels, Moll, Lebeulleur de Courlon, Bourgois, etc. Notwithstanding the multiplicity of these researches, and the care generally attending them, there is still great uncertainty with reference to the constants in the equation (B). This is due to several causes; first, to the inherent difficulty of the subject. It is difficult to produce a motion actually uniform; the measure of resistance is very delicate and is difficult to separate from the influence of the resistances of the apparatus employed. Again, the writers have almost all taken different points of observation, and this makes it difficult to compare their results. The majority have entirely neglected the lateral resistance; others who have taken it into account have represented it in formulas of interpolation of different forms distinct from formula (B). The coefficients of each experimenter correspond to the circumstances in which he is placed; and do not fit different conditions.

Still, to convey some idea of the value of the coefficients, we will give results selected from the best sources.

Dubuat caused 3 rectangular parallelopipedons with base a foot square, and having respectively altitudes of 4 lines, 1 ft. and 3 ft., to move in water. Neglecting lateral resistance, he obtained for k the values 1,43; 1,172; 1,102. But these coefficients seemed to him to vary with the velocity, a fact doubtless due to the neglected lateral resistance. In the experiments made by Borda upon thin plates moved in a circular direction, he obtained for k values varying according to the extent of surface, from 1,39 and 1,49 to 1,64. The radius of the mean circumference was 1,20 m. The variation of the coefficient was explained by the inequality of velocities at different distances from the axis of rotation. In similar experiments Hutton found $k = 1{,}24$ and 1,43; Thebault, 1,525 and 1,784; the latter with larger surfaces and higher velocities. For thin plates Col Beaufoy found $k = 1{,}13$; Col. Duchemin, 1,254. For prisms and cylinders moved in the direction of their axis, Beaufoy found values varying from

0,88 to 1,16. In all these experiments the coefficients diminished notably if the anterior ends had a rounded form. As to the lateral resistance, M. Bourgois, in a discussion of the experiments of Beaufoy, derived for a and b the following values :

In the first series of experiments,

$$a = 0{,}000125,\ b = 0{,}000102.$$

In the second series

$$a = 0{,}000100,\ b = 0{,}000125..$$

In the third series

$$a = 0{,}000024,\ b = 0{,}000156$$

In representing the friction of water in canals M. de Prony has used the values

$$a = 0{,}000044,\ b = 0{,}000309,$$

and Eytelwein, the values

$$a = 0{,}000024,\ b = 0{,}000366.$$

For conduits Prony gives

$$a = 0{,}000172,\ b = 0{,}000348.$$

Eytelwein

$$a = 0{,}000022,\ b = 0{,}000280.$$

These values refer to the mean velocity of the fluid, not to the velocity along the side.

The reader can consult "L' Introduction à la Mècanique Industrielle" of Poncelet, and M. Bourgois' "Memoire sur la Resistance de l'Eau," where the leading experiments are reported and discussed. The uncertainty affecting the constants shows that our knowledge in this matter is insufficient; and it explains why the theoretical researches of Daniel Bernouilli, Euler, Navier, Poisson, Caudey, and others, upon the important question of the resistance of fluids, have not yet led to any practical result. It is probable that the effects produced under the hypothesis that each element of the surface is subjected to the action of two forces, one normal, expressed by

$$k\,\mathrm{W}\,d\mathrm{S}\,.\,\frac{(\mathrm{V}\,\mathrm{Sin}\,i)^2}{2\,g};$$

denoting by i the inclination of the element considered with reference to the relative velocity; the other, tangential; expressed by

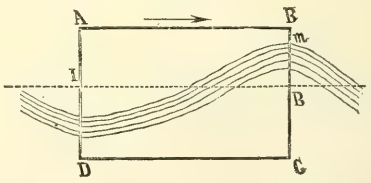
$$\mathrm{W}\,a\,\mathrm{S}\,(a\,\mathrm{V}\,\mathrm{Cos}.\,i + b\,\mathrm{V}^2\cos^2 i).$$

By projecting these forces in the direction of the motion, and integrating for the entire extent of the wetted surface, we should find the expression for the resistance for any assigned form; and a small number of well-conducted experiments, might possibly, with the aid of the method of least squares, determine the values of the coefficients a and b. But this work still remains to be done.

IV. According to Beaufoy's experiments, the resistance opposed to the motion of a body entirely submerged increases with the depth of immersion. Jorge Juan, a Spanish authority of good repute, in his "Examen Politico y Maritimo," says, that the resistance at an exterior point of a hollow vessel moving in water is proportional to the height due to the relative velocity with which the fluid would enter the vessel if the wall were pierced. The Marquis de Potesat in his "Theorie du Navire" has reproduced the ideas of Jorge Juan. This hypothesis makes the resistance depend on the depth of immersion; but ingenious as it is, it does not lead to results conformable to facts, and of course cannot be admitted. Still this point should be elucidated by special experiments, in view of the fact that the deviation of vessels driven by the screw propeller cannot be explained except upon the hypothesis of the increase of resistance with increase of depth.

V. In the case of floating bodies, the phenomena described at the commencement of this article, occur in the horizontal sections and the inferior portion of the body; but the free surface of the liquid presents new peculiarities. The molecules which meet the anterior face (B C, Fig. 3)

Fig. 3.



not being able to pass over this face, rise to a certain height proportional to the height due to the relative velocity; thus forming a kind of liquid cushion in front. But behind, there is a partial vacuum, into which the neighboring particles are precipitated, from which there results a lowering of the level at the posterior face A D. The difference of level at the points is called the *denivellation*. The molecules forming the cushion in front pass along

the sides in the curve represented in the figure. Let the dotted line represent the level of water before motion. If the anterior pressure is measured it is found greater than the static pressure P by a quantity proportional to $\frac{V^2}{2g}$, which may be represented by $m\,W\,A\frac{V^2}{2g}$; denoting by A the right section of the wetted portion and by n, a numerical coefficient. But if the pressure behind is measured it is found less than P by a quantity $n\,W\,A\frac{V^2}{2g}$. The difference of pressure may be denoted by $(m+n)\,W\,A\frac{V^2}{2g}$ or $k\,W\,A\frac{V^2}{2g}$; as in the case of a body entirely immersed. The lateral resistance can be expressed as in formula (B). But the denivellation produces another effect. It increases the surface in front by a quantity $m\,H$, proportional to $\frac{l\,V^2}{2g}$; l being the length of the prism. It diminishes the surface behind by a quantity proportional to the height due to the velocity of the molecules which descend from the level of the water to supply the vacuum; that is, it is proportional to $\frac{l\,V^2}{2g}$. Hence, the pressure in front is not $P+m\,W\,A\frac{V^2}{2g}$, but $P+m\,W\left(A+a\frac{l\,V^2}{2g}\right)\frac{V^2}{2g}$; a being a numerical coefficient. And for the posterior surface we have, not $P-n\,W\,A\frac{V^2}{2g}$, but $P-n\,W\left(A-\beta\frac{l\,V^2}{2g}\right)\frac{V^2}{2g}$, β being a new numerical coefficient. The difference of these pressures is

$$(m+n)\,W\,A\frac{V^2}{2g}+(m\,a-n\,\beta\,W\frac{l\,V^4}{4g^2}$$

or

$$k\,W\,A\frac{V^2}{2g}+k^1\,W\,A\frac{l\,V^4}{2g^2}.$$

The total resistance, therefore, is

$$R=k\,W\,A\frac{V^2}{2g}+W\,S\,(a\,V+b\,V^2)+k^1\,W\frac{l\,V^4}{4g^2}$$

The uncertainty affecting the coefficients of resistance in the case of bodies entirely submerged also occurs in the case of floating bodies. The majority of authorities have taken into account only the first term, neglecting lateral resistance and the effect of denivellation. Bossut, in experiments upon prisms with rounded fronts, found values of k less than unity. Dubuat obtained values varying from 1,11 to 1,14. The last value refers to a prism whose length was four times the height of a flotation, and for which the effect of denivellation, neglected by the author, must have been considerable. To the same cause are to be attributed the magnitude of the coefficients found by Col. Duchemin; these varied from 1,33 to 1,85. M. Poncelet thinks that the coefficient 1,1, is nearly correct in ordinary circumstances. According to Bossut, it should be less than unity when the prism has a rounded front.

As regards the keels of vessels, *though* the total number of experiments is small, the results are more precise and comparable. The application of screw propellers to navigation has furnished an exact and relatively easy way of obtaining an uniform motion and measuring the resistance. The best means seems to consist in causing the vessel to move uniformly by aid of a screw propeller tow-boat, and measuring the resistance by a dynamometer set in the tow-rope; taking into account the excess of tension due to the weight of the cable. M. Bourgois made several experiments, as well as M. Leboulleur de Corlon. Several scientific commissions have measured by this and other methods, the resistance of different vessels; among them Le Charlemagne, Le Napoleon, L'Audacieuse, and Le Primauget. Experiments have also been made in England. M. Bourgois, in his memoir already referred to, in his discussion of the several experiments has been led to the following conclusions. If, conforming to the usage adopted in the marine, we replace A by B^2 (B denoting the side of a square equivalent to the immersed surface midship) we can write

$$R=B^2\,V^2\left(\frac{k\,W}{2g}+\frac{W\,S\,a}{B^2\,V}+\frac{W\,S\,b}{B^2}+\frac{k^1\,W\,l\,V^2}{4\,B^2\,g}\right)$$

or, uniting the terms independent of the velocity,

$$R=B^2\,V^2\left(K_1+K_2\frac{l\,V^2}{B^2}+K_3\frac{S}{B^2\,V}\right) \quad (D.$$

putting

$$K^1=\frac{k\,W}{2g}+\frac{W\,S\,b}{B^2}\,K_2=\frac{k^1\,W}{4g^2},\ K^3=W\,a.$$

Mr. Bourgois has found that for sailing war-vessels, double-coppered and in good condition, the length being less than four times the breadth, we may write

$$R = B^2 V^2 \left(2^k,00 + 0^k,16 \frac{l V^2}{B^2} + 0^k,08 \frac{S}{B^2 V} \right) \quad (8.)$$

For men-of-war steamers, double-coppered, in good order, keel wooden and double-coppered, the length five or six times the breadth

$$R = B^2 V^2 \left(2^k,20 + 0^k,14 \frac{l V^2}{B^2} + 0^k,08 \frac{S}{B^2 V} \right) (9.)$$

For war-vessels, double-coppered, in good condition, of good model, the length not being more than four and a half times the breadth

$$R = B^2 V^2 \left(1^k,80 + 0^k,14 \frac{l V^2}{B^2} + 0^k,08 \frac{S}{B^2 V} \right) (10.)$$

For advice-boats of fine model, the efficient $0^k,14$ should be replaced by $0^k,12$.

These formulas give for R values whose mean is nearly 3^k, $3 B^2 V^2$, for velocities of 11 knots, or 5.65 metres per second, for ships, frigates, and even corvettes. But the resistance increases rapidly as the absolute dimensions decrease, a phenomenon due to the influence of denivellation. These facts accord with the old experiments of Bossut, which gave $k = 1,5$ for a prism with a base having the form of the vessel amidship.

To calculate the surface S, an empirical formula is used, by which we have

$$S = 0,6\ L\ (l + t),$$

L being the length at water-line, l the breadth at beam, and t the draft; that is S is 0.6 of the lateral surface of the parallelopipedon circumscribed about the submerged portion of the hull.

VI. The experiments made in Scotland in 1833 upon rapid boats employed in navigation in canals, gave rise to the opinion that beyond a certain velocity the resistance experienced a considerable diminution. These experiments, which at that time made a great stir, gave rise to many industrial enterprises, which did not succeed; and many of these theoretical deductions have since been forgotten. The cause of the illusion was this: the liquid cushion which forms in front of a vessel moving in an indefinite fluid, forms a wave which is propagated like ordinary waves; but in a canal this wave, arrested by the sides, advances with difficulty, or not at all, in a narrow canal. This forms what Scott Russel calls the solitary wave. According to the experiments of McNeil on the Scotch canals, and of Morin on the St. Denis canal, the velocity of this wave is always that of the vessel, when its motion is uniform. If the boat receives a momentary acceleration, it may happen that it rises on the wave, the prow separating from the wave, as shown in Fig. 4;

Fig. 4.

and the resistance is for a moment diminished by a considerable quantity. But this is a kind of unstable equilibrium that will not last. If the boat slackens it resumes its place upon the crest of the wave, and the resistance resumes its first value; if the boat, on the contrary, receives a greater acceleration and rides the descending wave, then the solitary wave descends gradually, finally disappearing, and a new one forms in front. The diminution of resistance, therefore, follows some particular law, which cannot be considered as constant nor as a normal case. Separating the phenomena from the influence of the solitary wave, it is seen that the resistance increases with the velocity, not as its square, as Morin thought, but more rapidly, so that swift boats are governed by the general law expressed n formula (C). See the memoir of M. Bourgois already cited, and Poncelet's "Mecanique Industrielle."

VII. We have said that the laws of resistance should depend solely upon the relative velocity. But the accurate experiments of Dubuat and other authorities have led to a greater value for resistance in the case of a solid body at rest in a moving fluid than in the case of a solid body moving in a fluid at rest. Two considerations explain this apparent paradox. In experiments made upon rivers or artificial canals the *mean* velocity has generally been taken as the velocity; this is less than the velocity at the middle of the stream, where the body experimented upon is generally placed. If R is the observed resistance and U the mean velocity, we determine the coefficient k by the relation

$$R = k.W.\frac{U^2}{2g}$$

$$\therefore k = \frac{R \cdot 2g}{W U^2}$$

Using the velocity at the middle, V, for the same resistance,

$$R = k'.W.\frac{V^2}{2g}$$

$$\therefore k' = \frac{R \cdot 2g}{W v^2}$$

and

$$k = k'\frac{V^2}{U^2}$$

Hence one generally obtains a coefficient k greater than the actual coefficient k'. Again, in order that a fluid move uniformly, it is necessary that its surface should be inclined; the body and the fluid are therefore in the same relative situation as if the body were moving up an inclined plane formed by free surface of the fluid; consequently the resistance should be increased by the circumstance.

IRON AND STEEL NOTES.

Bessemer and Crucible Steel Castings for Gun Barrels, etc.—The great demand since the commencement of the war on the Continent for rifles has led to the adaptation by Mr. Foster, of Sheffield, of a patent by means of which barrels can be cast from a hollow bloom. They are cast with a chill centre, and then rolled into the centre instead of being drilled, and so preserving the original skin of the metal, and maintaining its strength of a uniform character. By being case-hardened they wear longer without fouling, are not liable to corrosion, whilst the cost is scarcely so much as the ordinary barrel. Mr. Foster has just had a Chassepot barrel cast, and it appeared to be all that could be desired. The invention is applicable to steel hoops for railway wheels, gun barrels, and the casting of cylindrical forms in Bessemer or crucible steel. The object of the improvement is to save the preliminary processes in the production of a "bloom" by casting it in a metal mould, with a movable metal pin centre, or core and cover, by which means a bloom is produced, and when re-heated is ready to be rolled and finished without requiring to be cut, hammered, or shaped, and so preserving the original skin of the metal without injury, giving increased strength to the article so produced. In carrying the improvement into practice a metal mould (by preference of cast-iron) is arranged in combination with a movable centre pin or core, and a cover or lid, which is also movable. The centre or core, with the lid or cover, are held in position by a colter, or otherwise, in such a manner that the cover can be caused to make a partial revolution to break off or remove the "get" or runner of the casting directly after the melted steel is run into the mould, the centre pin or core being then forced out, either upwards or downwards, as may be found most convenient, thus leaving the steel to contract uniformly throughout. The interior capacity of the mould is suited to receive the exact quantity of steel required for the production of a "bloom" for a hoop, tyre, or other article of given weight and dimensions. The metal centre or core may be made either solid or hollow. In like manner cylindrical forms may be made of cast-steel suitable for other purposes. Mr. Foster is at present in treaty for the production of a large number weekly of gun-barrels, and the invention is likely to turn out a very valuable one, and also effect a great improvement in the production of barrels of every description.—*Mining Journal.*

Interesting Experiments in Steel Manufacture.—We learn from the Troy "Press" that Mr. G. W. Ballou, President of the Knickerbocker Manufacturing Company, of Vermont, assisted by Dr. C. M. Neo, has lately been conducting in that city some interesting experiments in the manufacture of steel, which have attracted much attention among the iron and steel men of that locality. The object of these experiments was to test the qualities of the Codorus ore, and they are said to have been completely successful. One ton of Codorus ore was melted in a puddling furnace with five tons of common domestic pig, and the product was found to be five tons of steel of a good quality and capable of taking a high temper. The ore acts as a purifier, or vehicle for carrying the phosphorus, sulphur, and from the molten mass; and although a chemical analysis of this ore reveals the presence of no component element not belonging to iron ores in general, there is some allotropic condition or combination which gives it the peculiar qualities which render it so peculiarly useful for the conversion of pig-iron into steel. Subsequent to Mr. Ballou's experiments at Troy, a few heats were made at the Albany Iron Works. The ore and iron, thrown together into the puddling furnaces, were melted and balled up in an hour, resulting in steel which, when made up into cold chisels and tested, was found to cut English cast-steel. Another experiment, made about the same time at the Empire Foundry, which consisted in melting Codorus ore with Hudson River No. 2 iron in a cupola, was also found to be completely successful, and a trial of its properties in connection with fragments of burnt out iron, consisting of an old gas retort, grate bars, etc., showed that it imparted to such metal in the furnace the qualities in which it was most deficient. Experiments are shortly to be made with rolled rails of Codorus steel, with a view to testing their strength as compared with other all-steel rails of good quality, and much interest is manifested in the result.—*Iron Age.*

Improved Manufacture of Steel.—Mr. C. L. Franke, of Finsbury, has just patented the following chemical mixture for making steel of high quality:—26.9 parts of boracic acid, 21.5 parts of spathose iron ore, 13.4 parts of hydrochlorate of soda, 10.3 parts of prussiate of potash, 8.6 parts peroxide of manganese, 6.1 parts of dry carbonate of soda, 3.9 parts of magnetic iron ore, 3.7 parts of graphite, 2.8 parts of cyanide of potassium, 2.8 parts of red iron ore. Total parts, 100.

Cast-iron is melted in a puddling or similar furnace, together with 7 or 8 per cent. of hammer slag, and 1 or 2 per cent. of the chemical mixture. The metal is well rabbled so as to thoroughly mix

it with the chemicals. When it boils, as it will do under this treatment, a further quantity of the chemical mixture is added, say about 1 per cent. Afterwards the metal is balled up, and it may then be hammered or squeezed and rolled into bars in the usual way. This steel may in the form of puddled ball or otherwise be melted in crucibles for the manufacture of cast-steel; sometimes the puddled balls or other blocks or pieces of steel are heated and sprinkled with about 1 per cent. of the chemical mixture. A number of puddled balls are then welded together, and drawn down so as to obtain a forging of any required shape.

RAILWAY NOTES.

NARROW GAUGE RAILWAYS IN THE UNITED STATES.—There are few questions of more practical and pressing importance in the present day than the best means to be adopted for extending our railroad system (carrying with it as it does fresh life and energy into all the districts which it penetrates) into the territories and other parts of this vast Union, where the traffic to be expected, at any rate for years to come, cannot be such as to warrant a large capital expenditure.

It is therefore with much satisfaction that we place before our readers the following information kindly given to us by Sir Charles Fox & Sons, the well known civil engineers of London, who have for many years been actively engaged in practically working out a similar problem in Australia, India, and Canada.

Their object has been to construct railroads, which, whilst very economical in first cost, should be substantially built and equipped, and therefore operated and maintained at a moderate percentage of the gross income.

Mr. Carl Pihl, the engineer of the Government railway of Norway, has also for some years been carrying out very successfully a system almost identical with that under review.

The question of gauge is one which requires to be determined after careful investigation of the circumstances in each case. Where a standard national gauge exists, caution must of course be exercised in introducing any diversity; and yet it may, upon examination, be found that to adhere in all cases to the gauge suitable for trunk roads would be to check, nay, even to prevent, the constructing of many tributary or branch roads, in themselves most necessary for the development of the country. Thus, in the vast empire of India, where the trunk roads have the 5 ft. 6 in. gauge, the Government is seriously and favorably entertaining the question of adopting a much narrower gauge for the tributary roads, to open up the country.

With the above reservation, Sir Charles Fox & Sons, and others interested in this question, have found, after an experience spread over many years, that the most economical gauge for such tributary roads which can be used with advantage is that of 3 ft. 6 in. A broader gauge than this is, in their opinion, for speeds of 25 miles an hour and moderate traffic, quite unnecessary, and of course involves additional outlay, especially if the country is of a hilly nature. To use, on the other hand, a narrower gauge than 3 ft. 6 in. is likewise very objectionable, and especially so where wood is the fuel chiefly employed, as on very narrow gauges it becomes impossible to use either boilers or fireboxes of such dimensions as to give satisfactory results.

The following are given as examples of railroads which have been built, or are now in progress of construction upon this gauge:

EXAMPLES AND COST IN GOLD, INCLUDING IN EACH CASE STATIONS, ROLLING STOCK, ENGINEERING AND ALL MANAGEMENT EXPENSES.—1st. The Queensland Railways, Australia. Length, 222 miles; gauge, 3 ft. 6 in. Wages: skilled laborer, $2.50 to $3.10; ordinary do., $1.50 to $1.75. Average cost per mile, $32,000.

2d. The railway from Conyeveram to Arconnur, India. Length, 19 miles; gauge, 3 ft. 6 in. (Land and portion of road-bed given by Government.) Materials chiefly sent out from England. Rails 35½ lbs., iron. Average cost per mile, $19,000.

3d. The Toronto, Grey and Bruce, and the Toronto and Nipissing Railways, Canada. Length of first section, 193 miles; gauge, 3 ft. 6 in. Wages: ordinary laborer, $1 to $1.50. Average cost per mile, $14,150.

4th. The Government railways, Norway (constructed by Carl Pihl, C. E.). Length, 106 miles; gauge, 3 ft. 6 in. (Rails and many other materials sent out from England.) First, through easy country, $15,900 per mile; second, through heavy country, $23,700 to $26,150 per mile.

It will be seen that the two first of these principles being conceded, it at once becomes possible to construct a thoroughly substantial track with rails not weighing more than from 30 to 40 lbs. per linear yard, provided that the ties are laid sufficiently close, the rails well fished at the joints, and an ample supply of ballast provided.

The speed of 25 miles an hour is found in practice to be more than sufficient for tributary roads. A load of 4 tons per wheel is sufficient to enable the passenger and freight cars to be of ample dimensions for convenience of traffic.

The passenger cars of latest design are of the usual American type, 32 ft. long, exclusive of platforms, and 8 ft. 6 in. wide, carrying very comfortably 32 passengers. Their centre of gravity being very low, they run with great steadiness. The box cars are 15 ft. long and 8 ft. 6 in. wide. The platform cars are 24 ft. long and 8 ft. 6 in. wide, and carry 10 tons, their own weight being only 5 tons.

It will thus be seen that the non-paying load, or dead weight, is reduced from the usual proportion of one-half to one-third of the gross weight; and from this results an important saving in operating expenses.

The locomotives are generally of 2 types.

Type 1, or freight engine, has 11-in. to 12-in. cylinders; 6 coupled wheels, 3 ft. 3 in. in diameter, and a 4 wheeled bogie, and weighs about 20 tons, exclusive of tender.

Type 2, or passenger engine, has 10-in. to 11-in. cylinders, 4 coupled wheels, 3 ft. 3 in. in diameter, and a 4-wheeled bogie, and weighs about 16 tones, exclusive of tender.

The maximum grades vary from 100 to 132 ft. to the mile. The sharpest curves are of from 500 to 330 ft. radius. The grading has generally a width in cuts of 15 ft., and on banks of 12 ft. The bridges are sometimes of iron, with masonry substructure, sometimes altogether of timber. The depots are of neat but economical design. The railroads are generally fenced throughout.

On the Canadian roads careful arrangements are

made to protect the track from snow and to provide in every detail against the effects of frost.

The cost of the Canadian roads, viz., about $14,000 per mile. may be taken to fairly represent the probable outlay (including evrey expense of right of way, management, etc.) for the building and equipping of a road of this gauge through an undulating and well-settled country, involving considerable expenses for right of way, say, 15,000 cubic yds. of grading per mile; frequent road-crossings, fencing throughout, and a fair proportion of bridges, depots, side-tracks, and an ample equipment for a considerable traffic.

On the other hand, in the great prairie country of the West, where right of way, grading, and bridging are at the minimum, where 36 lbs. rails would be ample, where fencing is not necessary, and where the provision for depots, side-tracks, and equipments. could be materially reduced, a well constructed and substantial railroad of the 3 ft. 6 in. gauge may be completed *and equipped* ready for operating, with an expenditure not exceeding from $8,000 to $10,000 *per mile*, and on such a road, as both grades and curves would be easy, trains carrying a net load of 100 tons of freight could be operated with facility, at a speed of from 20 to 25 miles per hour.

Operating.—So far as the gauge is concerned, the cost of traction would be very much the same per train mile, and per ton, as on railroads of the ordinary 4 ft. 8½ in. gauge, were it not reduced by the much more favorable proportion which the net or paying load bears to the gross weight of the train. Moreover, in consequence of the lower speeds and the light-rolling loads, there is on these light railways a most important saving in wear and tear, both of tracks and equipment, and the total cost of operating is therefore considerably reduced.

Peru is constructing 3 great railroads to connect her coast with the countries east of the Andes. The one from the coast to Arequipa, and across the Andes to Puno, and thence to Lake Titicaca, on the dividing line between Peru and Bolivia, is progressing favorably. Forty miles have been finished between Arequipa and the coast, and traversed by powerful engines with construction trains. There are 6,000 laborers at work on the road. The difficulties of the mountainous ground are tremendous, bu t have been triumphantly overcome. Many o f the huge cuttings and embankments have called out the highest kind of engineering skill. Within 6 months the ancient city of Arequipa, founded by Pizarro, away up in the vale of the Andes, will be in close communication with the coast. The region around Arequipa is rich in silver and copper mines, and produces cotton, wool, sugar, and nitre, the exports of which have been comparatively inconsiderable for want of cheap transport. This the railroad will give, and will inspire new life into the commercial and social relations of those productive but hitherto little known elevated valleys of the Andes.

By the census of 1870, the population of Minnesota, is given at 435,511; of Washington Territory, 23.901; of Oregon, 90.922. The population of the intermediate territories, are Dakotah, 14,-181; Montana, 20,594; Idaho, 14,998. We are not in possession of any returns of population of the British possessions, but there are many important settlements which will be tributary to the Northern Pacific road. With regard to Minnesota, the division extending from Lake Superior to the Red River of the North, 250 miles. is now well advanced, and it is expected that by mid-summer this section will be in full operation. This division includes a branch to Pembina, on the British border; besides which. the finished line of the St. Paul and Pacific road, recently purchased and consolidated with the Northern Pacific, will give to the Company 600 miles of road in Minnesota, completed or under construction. Meanwhile, orders have been sent to the Pacific for the commencement of work on the western section early in the spring, when the work will be pushed forward in both sections as speedily as is consistent with solidity and economy.

As an important adjunct to the road, the company is now organizing a department of Emigration and Colonization, claimed to be comprehensive, practical, and on a scale hitherto unattempted by any corporation or government.

The extensively ramified connections of the house of Jay Cooke & Co., in Europe and America, no doubt, afford important facilities in aid of this scheme.

We have already pointed out, in a general way, the principles which must insure the prosperity of the road and country through which it passes. The following points, as set forth in the prospectus of the Company, present a more particular view of its commercial advantages:

The business of the road, immediately on its completion, and even during construction, will be very large, and will consist mainly of: 1. The transportation of Government mails, troops and military supplies. 2. The large local carrying trade of the present population of the States and Territories traversed. 3. The entire trade of the important British settlements occupying the rich valleys of the Red and Saskatchewan rivers, the Winnipeg basin, and the fertile plains of British Columbia, on the Pacific slope. 4. That portion of the large through business between the Atlantic and Pacific oceans, which will certainly pass over this line, owing to its great superiority in directness, shortness, and ease of grades. 5. The constantly increasing carrying trade of the millions of people who will soon occupy the magnificent country through which the road passes, and the transportation of whose supplies and products alone, will speedily constitute a paying business for one line of road.

This road will unite Lake Superior and St. Paul with Puget sound—and hence the commerce of the lakes and of the Mississippi river with that of the Pacific Ocean—by a line, counting actual distance and difference in grades, at least 500 miles shorter than the present one connecting Lake Michigan and San Francisco. By it, Liverpool and New York will be brought 1,400 miles nearer than now to the ports of China and Japan. It will be the only-trans-continental line under one control.

Branch lines or feeders will be built from the Trunk road, northward and southward, so as to drain the entire region north of latitude 42 deg., and render the future construction of additional east and west lines within that belt unnecessary.

In consequence of this difference of elevation, the road will in ordinary winters, be less encumbered by snow where it crosses the mountains, than are the passes at the elevated more southerly points. The difference of 5 to 6 deg. of latitude is more than compensated by the reduced eleva-

tion, and the climatic effect of the warm ocean-currents from the equator, which strike the Pacific coast and extend their tempering influence far east of the Rocky mountains.

In conclusion, we give the following approximate estimate of the cost of construction, made by the chief engineer of the Company, W. Milnor Roberts, Esq., who with others, in 1869, made a preliminary survey of the line of road:

Grading, masonry, bridging, track and ballast	*$60,320,000
Sidings, etc	4,200,000
Contingencies, including superintendence and engineering	5,000,000
Telegraph line	600,000
Buildings	2,312,000
Rolling stock	3,615,000
Branch road	1,200,000
Extra works, etc	800,000
	$78,047,000
Interest on bonds over receipts during construction	7,230,000
Total	$85,277,000

This gives an average of $42,638 per mile.

As the line of country over which the Northern Pacific railway is building, presents the compensation of lower altitude for higher latitude, in contrast with other routes, we present a comparison of grades:

Northern Pacific to	Miles.	Average height above the sea.
Dakota valley	300	1,200 feet.
Yellowstone river	300	2,200 "
Along Yellowstone	400	2,500 "
Flathead valley	300	3,500 "
Lewis or Snake river	200	3,000 "
Puget sound	500	400 "
	2,000	
Lake Superior to Puget sound via Portland	2,000	
Direct line	1,775	

Central Pacific—from Chicago to	Miles.	Average height above the sea.
Omaha	491	1,000 feet.
Cheyenne	516	3,300 "
Cooper's	86	7,300 "
Promontory point	482	6,200 "
Humboldt	408	4,750 "
Reno	130	4,000 "
Auburn	118	4,400 "
Sacramento	36	300 "
San Francisco	138	50 "
	2,405	

The future which this movement unfolds, belongs to that domain in which facts make up a grandeur glorious as the imagination loves to draw. It makes new States for the American Union. It will bring about the greatest alliance yet of American and European capital. It will give ready connections with the fisheries of the North Pacific. On the direct line to the East, Shanghai comes more than 1,500 miles nearer to our Atlantic coast. From the wharves on Lake Superior, vessels can pass with unbroken cargoes to the great ports of Europe. But to describe all the ends it will serve, transcends our ability. To us it is, as it will be found by others, a study which gives a larger understanding of the probabilities of the age in which we live.—*From the American Exchange and Review.*

* Being the estimated cost apart from siding, etc., of the six divisions, viz.:

No. of Div.	Description of Divisions.	Miles.	Estimated Cost.
1.	Lake Superior to Yellowstone river	550	$13,750,000
2.	Along the Yellowstone to Bozeman's pass	420	11,760,000
3.	Bozeman's pass to Hellgate river, Mountain division	225	9,600,000
4.	Hellgate river to Pend d'Oreille lake,	205	7,000,000
5.	Pend d'Oreille lake to the mouth of Lewis river	223	7,500,000
6.	Mouth of Lewis river to Puget sound, Columbia Valley division	377	11,310,000
			$60,320,000

ORDNANCE AND NAVAL NOTES

THE PRUSSIAN NEEDLE-GUN.—The superiority of the present method of loading fire-arms at the breech over the old-fashioned manner of loading at the muzzle, is now universally conceded. Arms constructed on this principle are peculiarly adapted for the military service, on account of the confidence which they inspire in the troops so armed. As complete a revolution in the science of warfare has been effected by the introduction of the breech-loading system, as was formerly produced by the substitution of rifles for smooth-bores, or the percussion-cap for the flint lock. This innovation has been gradual, for the principle itself is by no means novel.

Henry II. of France is supposed to have invented breech-loaders as early as 1540; but in China and some parts of the East this principle had been applied to large guns many years before. The wall pieces of the French were so constructed at a later period, and still later a chamber-loading musket was used by some of the Norwegian infantry. But the Germans are entitled to the credit of having early recognized the great importance of inserting the charge in the breech for the purpose of facilitating the loading and thereby increasing the rapidity of fire. In advance of all other nations they extensively adopted in their army a gun so arranged, known as the needle-gun.

It has been erroneously asserted that this gun was invented by an Englishman named Sears, and exhibited in England prior to its adoption by the Prussians. This misapprehension has arisen from the fact of a gun having been invented by M. A. Sears, of London, after the Prussians had adopted theirs. The real inventor was a manufacturer of guns at Sommerda named Dreyse. His first model was made in 1835, and was a muzzle-loader. In this early model the rear end of the barrel, or breech, was securely closed by two screws, one in front of the other, with an intervening space containing a sliding needle operated by a spiral spring. At the bottom of the cartridge there was a priming of a very explosive composition, which ignited the charge of powder by the friction of the needle penetrating it. On account of the highly explosive character of the cartridges, premature explosions frequently occurred while they were being rammed from the muzzle. The balls did not always expand into the grooves and take the rifling of the barrel, on account of too great windage. These serious defects, which impaired the efficiency of the gun, caused the inventor to change the method of loading from the muzzle to the

breech, and originated the present form of the needle-gun (zundnædel gewehr).

It was first distributed to the Guards of the Prussian army as a rifle in 1848, and gave great satisfaction. During the Schleswig-Holstein war the needle-rifle was tested in service a little, and the trials resulted favorably. In 1855 a rifle-musket (needle) was issued to those regiments of infantry that were without the rifle. Subsequently some of the chasseurs and riflemen of the Guards were armed with the rifle, it having an improved sight and a different form of ball.

The needle-gun is so called from the thin wire or needle which discharges the piece. The weight of the rifle is 11 lbs. 4 oz., and it is capable of being fired about seven times per minute. It is composed of three principal parts—the barrel, the stock, and the breech-loading mechanism, including the needle, etc. As the stock does not differ materially from those of other arms, no description is necessary. It is somewhat straighter than those of this country, and made from lighter wood.

The barrel is rifled for three feet of its length, and has a bore about six-tenths of an inch in diameter, with a chamber for the cartridge in the rear end, which is slightly larger than the bore. The rifling consists of four grooves of uniform depth and width; each .24 in. wide, and .03 in. deep, with a uniform twist of five-elevenths in the length.

The mechanism for loading at the breech is a slide or plunger that opens or closes the rear end of the barrel by sliding in a cylindrical socket fastened to the barrel by a screw thread. This socket or cylinder incloses all the mechanism for loading, and is attached to the stock by a tang and screw, which also passes through the trigger-plates. The cartridge is inserted into an opening on the right side of the socket, and forced into the chamber by the plunger, operated by a knob handle. This plunger is a cylinder having its front end reamed out to fit the end of the barrel, which is cone-shaped externally. An air-chamber is formed in the plunger by a space between its front end and the chamber of the barrel, that contains a tube called a needle conductor through which the needle slides. The needle conductor is screwed into an iron plate in rear, that receives all the force arising from the reaction of the gas at the instant of discharge. Behind this, another tube is situated (called the locket) which contains within it a small tube with projecting rings and a spiral spring inclosing the needle. The locket has a slot and recess for its spring.

The needle is a very thin steel wire, sharpened at the front point, and soldered at the other end to a brass stem, which is screwed into the tube with the spiral spring,

Although the spiral spring is quite light, it will support a weight of eleven pounds. On the under side of the cylinder is the trigger, trigger-spring, and stop. The trigger is an irregular-shaped bent lever, which accomplishes the discharge of the rifle when pressed, by releasing the lock of the needle.

For the rifle the cartridge is composed of a sphero-conical leaden ball of 450 grains weight, a paper sabot with a priming of fulminate, and a charge of 56 grains of powder enveloped by paper. The sabot is a paper wad, shaped in dies by machinery to fit the spherical base of the ball, with a recess in its bottom for the priming. In the manufacture and preparation of the explosive composition, the greatest secrecy has been observed by the Prussian authorities—an unnecessary precaution, as either of the fulminates of mercury or silver are as good, if not a superior agent. Behind this wad is the charge of powder, so that the needle, to reach the priming, penetrates the charge, and the grains of powder nearest the ball are first ignited. By this method of ignition the ball is started before it is acted upon by the explosive force of all the charge, and increased range and diminished recoil are claimed.

The rifle-musket, before alluded to, is lighter than the rifle, weighing only 10 lbs. It has five grooves of uniform depth and twist, of one turn in 64 in. The ball is a cylinder with a conical front, and weighs 705 grains; 79 grains of powder is the charge. The sight for the rifle is only graduated to 490 yds.; for the musket, it extends to 1,000 yds.

Such is a brief description of the famous gun with which the Germans waged their successful war against Austria, and demonstrated to the world the advantages of the breech-loading system. But notwithstanding some merit which their boasted gun certainly possesses, there have been so many important improvements made since the invention of the needle-gun, that it has ceased to be even an efficient weapon in comparison to those of later date. It owes its celebrity only to the fact of its being the first breech-loader used extensively for military purposes, and as a type of the new system. Even to this day, on the plains of the West, its name is synonymous with that of its method of loading, and all such class arms are called needle-guns.

An enumeration of the many systems of loading at the breech would fill a volume. They have been classified into two divisions—the old and new. The latter include all those that are arranged for a metallic cartridge, while the old class use paper ones.

One of the great objections which has been urged against loading at the breech, is the difficulty of forming such a tight joint at the point of explosion, as to prevent the escape of considerable gas. This is remedied by the use of the metallic case cartridge, which acts as a gas check. Such a cartridge is in use in our service, and is vastly superior to the paper cartridge of the Prussians. In fact, the needle-gun, for rapidity of fire, accuracy, range, penetration and endurance, is far below the standard of the U. S. Springfield breech-loader.

In March last a board of officers convened in St. Louis for the trial of small arms, and subjected the Springfield musket to the following severe tests:

For exposure to the weather—five hundred rounds to be fired without cleaning, and exposed to the sun and rain.

For effects of sand and dust on the breech mechanism—eight shots to be fired, then fine sand to be sifted over the breech mechanism, closed; eight shots, and fine sand sifted over the same parts open, and nine shots fired.

For effects of salt water—the arm to be placed three hours in brine, then exposed in open air until next day, and fifty shots to be fired.

For strength of breech mechanism—to be fired once with double and once with triple charge of lead and powder.

The musket stood the above trial, and worked well when quite rusty.

The complicated and delicate mechanism of the

needle-gun is ill adapted for such experiments. It would be absurd to institute a comparison between the two arms. An invention of nearly thirty years ago in this progressive age of advancement in all mechanical contrivances, cannot compete with anything modern, and the needle-gun would prove a clumsy weapon if it were matched against an English or American rifle of late pattern.

ENGINEERING STRUCTURES.

Wire Tramway in Colorado.—We make the following extract from a letter from Mr. Geo. W. Cypher, of Lambertsville, N. J. It describes a wire-rope tramway, constructed by Mr. Cypher for the Brown Silver Mining Co., of Clear Creek Co., Colorado, in 1868:

It consists of two main cables, $1\frac{1}{8}$ in. in diameter, securely anchored in the rock at the head of the plane 7 ft. apart, then passed over a tower 15 ft. high, and at points down the mountain where, comparatively secure from avalanches, are supports at intervals of from 250 ft. to 370 ft., capped with cast-iron saddles, in which the cables rest in such manner as will permit a pulley running on the cable to pass freely over them.

At the foot of the plane the cables are each attached to an eye-bolt 3 ft. long, with thread cut for 2 ft. of its length, and pass through a brass beam at the top of a tower 30 ft. high. The long eye-bolt is intended to take up any undue slack that may take place from the striking of the cable.

The tower is prevented from overturning by two short cables attached to its top and pass back and down to a timber crib filled with stone.

This completes the track ready for the cars.

The cars are made of stout sheet iron, the bodies kept about level by the upper suspender being the longer. The suspenders stand "fore" and "aft," so that the pulleys are 9 ft. apart, with gas pipe strut to keep them in position. So each car is suspended on two pulleys, 9 ft apart, and 13 in. in diameter. One car being on one main cable at the head of the plane, the other on the other cable at the foot of the plane, a wire rope, $\frac{5}{8}$ in. in diameter, is passed round a grooved wheel of diameter equal to the distance between the cables (7 ft.); placed horizontally in the tower at the head of the plane, and crossed in front; it is attached to the upper end of each car. This grooved wheel has a hand-brake on it, to regulate the speed of the cars when descending.

From 1,500 to 2,000 lbs. of ore is taken at one load.

On reaching the foot of the plane, the car is dumped by dropping the bottom, the ore descending by a shoot into a bin near the crusher.

To keep the cars steady in position, and to prevent them running up the plane back and fore when the load is discharged, a counter or tail-rope, of $\frac{3}{8}$ in. in diameter, is attached to the lower end of each car, and passes round a grooved wheel, suspended in a sliding frame in the tower at the foot of the plane. The running-rope and tail-rope are carried over rollers at each support along the line.

This arrangement has been in constant operation since September 1st, 1868, and was divulged by me the forepart of June, 1868.

There are now quite a number of planes on the same plan in operation among the mountains of Colorado.

During July, 1868, and while putting up the plane on Brown Mountain, I proposed to erect a line 4 miles or even 8 miles up Clear Creek, to transport freight and passengers, and use the water-power of Clear Creek to propel the cars.

I have no patent, for the reason that at that time I did not deem the invention of sufficient importance. But, as the system has since attracted considerable attention among scientific men, I feel that I am entitled to a share of the credit of originating it, and, at all events, to prevent any one else claiming the invention and patenting it in this country.

Postal Pneumatic Tube.—A large party of visitors were invited. on Saturday. to the General Post-office, to see the working of a new line of pneumatic tubes for the telegraph service, between Telegraph street, in the City, and Temple bar, upon the Siemens principle, originally brought out in Berlin some five or more years ago, but now for the first time adopted in this country. Pneumatic carrier-pipes, upon Mr. Latimer Clarke's system, have long been in use at the Telegraph street station for short distances eastward, but the present line is the first coming thence westward. In the Clarke system, the two sets of pipes are open at their terminal ends, and are both worked by a steam-engine at the head station, which forces air into one stationary cylinder or receptacle there, and exhausts a vacuum in another. The carrier-box, in which the messages are placed, is thus blown through the "down" tube and sucked back through the "up" tube. The service is admirably conducted in this way from one place to another, but no intermediate station is practicable. In the Siemens system, the "up" and "down" tubes are continuous, the engine pumping air into the one end and exhausting the other, so that a continuous circulation is maintained, and which can be cut by any number of intermediate stations. These "stations" are formed by short lengths (about 2 ft.) of double tubing, placed parallel side by side, inserted in the main pipes, and working backwards and forwards on a rod or hinge. One of these, the "siding," is covered with a glass top, and has a perforated stop at one end, against which the carrier-box is "trapped" or stopped, the perforations in the "stop" allowing some of the current of air to pass through, so as not to arrest the circulation of the air-current, which is further completed by a bent tube passing over from one end of the main tube to the other across "the station," and actuated by a throttle-valve. The "main line junction-pipe" and its companion "siding" are worked on the same "block" system as the metropolitan lines of railway. A signal-bell or gong denotes that a "carrier" has been dispatched by the "up" or "down" tube respectively, and the number of the sounds struck indicate the station it is intended for. That station immediately puts on its "siding," and as soon as the carrier arrives it is duly "trapped." The "siding" is then brought over, and a straight rod inserted forces the carrier-box out, and the messages are duly received. In passing intermediate stations, the carriers strike the stud of a bell inserted in the main tube junction-pipe, and notifies its transit; the object of the "block" system being that two "carriers" shall not be in the same length of tube at the same time, for fear of stoppages at any sharp turns or bends; for, although, if any such accident occurred, it could be readily

relieved by reversing the air-current, it is desirable in a public service to have no chance of any, even temporary, interruption. The length of the new pneumatic line is about a mile and a quarter. From Telegraph street to the General Post-office, 880 yds.; thence to Temple bar, 1,330 yds. The system was explained by Mr. R. S. Curley, C.E., the engineer-in-chief of the telegraph lines. Working with pressure and vacuum, or by the proper circulation, the time taken by the "carrier" from Telegraph street to the General Post-office was 1½ minutes; thence to Temple bar, 2½ minutes; or right through the whole distance in 4 minutes. Worked by vacuum only, the "carrier" took 8½ minutes for the same total distance.

CENTRIFUGAL PUMPS.—At a meeting of the Institution of Civil Engineers held on the 14th inst., the second paper was on Centrifugal Pumps, by Mr. D. Thomson, Assoc. Inst. C. E. In this communication a short sketch was given of the early history of centrifugal pumps, and it was stated that their practical introduction as useful machines dated from the Exhibition of 1851. The author attributed to the late Mr. J. G. Appold, Assoc. Inst. C. E., the principal merit of bringing them to such a stage of perfection as to make them generally available. Mr. Appold made numerous and careful experiments, and the results thus arrived at had been confirmed by the author's experience.

The practical rules of construction were thus stated:

1. The arms of the fan were curved backwards, according to principles of construction which were explained by diagrams. The depth of the fan was one-fourth of the diameter, and the central opening for the admission of the water was about nine-sixteenths of the diameter. The space allowed in the case round the fan should be of ample dimensions.

2. The best duty was given when the speed of the periphery of the fan exceeded the velocity of a falling body due to the height of the lift, by from 6 ft. to 8 ft. per second.

3. A fan 12 in. in diameter, and proportioned as described, would discharge 1,200 gallons of water per minute.

4. If the diameter of the fan was varied (the speed of the periphery and the lift remaining the same) the delivery of water was increased or diminished directly as the square of the diameter.

5. When a centrifugal pump, properly proportioned, was worked by a steam engine, the duty that might be realized ranged from 55 per cent. in the smaller-sized pumps to 70 per cent. in the larger machines, of the power shown by the indicator diagrams.

The theoretical principles on which the curves of the arms should be formed were explained and illustrated by diagrams, and easy methods were described of arriving at close approximations to these curves by arcs of circles. The conditions under which centrifugal pumps could be most advantageously used were stated to be when the lifts were low, not exceeding 30 ft., and especially when the lift was also variable, as the centrifugal pump had a self-adjusting property, by means of which as the lift diminished the quantity of water discharged increased. The tabulated results of experiments made with centrifugal pumps for emptying graving docks at West Hartlepool and at Leith, showed this self-adjusting quality of the pump, and generally illustrated the principles explained in the paper.

Drawings were given of three different kinds of centrifugal pumps that the author had made, adapted for different circumstances, and the special advantages of each were explained.

A note was appended to the paper, embodying a theoretical investigation as to the statical height of the column of water that a centrifugal pump should sustain by a given speed of the fan, and this was shown to be expressed by the formula

$$S = 9.82\sqrt{h}$$

where S = the speed of the periphery of the fan in feet per second, and h = the head of water supported by the pump in feet, no water being discharged.

It was shown that owing to the water exterior to the fan being carried round by fluid friction, the speed of the periphery must always be less than this, and in the smaller pumps it was found experimentally to be more nearly expressed by the formula

$$S = 8\sqrt{h}$$

—*Engineering.*

NEW BOOKS.

DESILVERIZATION OF LEAD BY ZINC. Translated by FREDERICK PRIME, Jr. New York, 1870. For sale by Van Nostrand.

This valuable memoir appeared sometime since in the columns of the "Technologist." It now appears as a neat little pamphlet of 20 pages, with folding plate and tables. The process, as described, consists of three stages. 1. Desilverization of the lead. 2. Refining the desilverized lead. 3. Treatment of the zinc scum. Compared with the Pattinson process, it is believed to possess great advantages.

THE QUARTZ OPERATOR'S HAND-BOOK. By P. M. RANDALL. Revised and enlarged edition. New York: D. Van Nostrand.

The object of the author in the preparation of this work has been to present a clear and comprehensive exposition of mineral veins and the means and modes chiefly employed for the mining and working of their ores, more especially those containing silver and gold.

The writer has had a large experience from which to draw material for the present book, but he has also availed himself of the skill and experience of other practical miners and millwrights, and duly acknowledges the same in the preface.

As is usual with works of such a technical character, an outline of the theoretical principles involved is added for the benefit of such readers as find the more complete treatises inaccessible. This applies in both Mechanics and Chemistry.

A collection of tables to aid in the calculations, is placed at the end of the book.

THE SUN RULER, FIRE, LIGHT, AND LIFE OF THE PLANETARY SYSTEM. By RICHARD A. PROCTOR, B. A., F. R. A. S. London: Longmans, Green, & Co. New York: Scribner, Welford & Co. For sale by Van Nostrand.

A new book from Mr. Proctor is always acceptable. No other writer of the present day affords us

so satisfactory a discussion of the present condition of astronomical knowledge.

The scientific deductions from late spectroscopic observations, are set forth in the present work in the clearest manner. The method of making the observations has never been so well described before.

The most attractive portion of the book to astronomical students, is, doubtless, that describing the methods of observing the transits of Venus, and the relative value to astronomy of the coming transits of 1874 and 1882.

The book is illustrated with 110 wood-cuts, and 10 lithographic plates, all of which are excellent.

A Complete Guide for Coach Painters. Translated from the French of M. Arlot, by A. A. Fesquet. Philadelphia: Henry Carey Baird. For sale by Van Nostrand.

This little book presents simply the principles which guide the artisan in one of the numerous branches of the art of painting.

As coach painting is a trade of itself, this compilation of technical rules is likely to prove of good service, while the chapters on the preparation of colors and treatment of varnishes will meet the wants of other artisans.

An appendix of 70 pages treats of coach painting as practised in England and the United States.

Elements of Machine Construction and Drawing, or Machine Drawing; with some Elements of Descriptive and Rational Cinematics. By S. Edward Warren, C. E. New York, John Wiley & Son. For sale by Van Nostrand.

This work is on an entirely new plan. Besides affording instruction in methods of machine drawing according to Prof. Warren's admirable method, it affords excellent instruction in the elements of mechanism. This latter branch of science has received too little attention in our technical schools; in fact, it has had none at all; the only instruction obtainable in this department has been that contained in one or two English books, and a few odd chapters in works on Practical Mechanics, and with which latter science Mechanism has been confused.

The methods of transmitting and modifying *motion* without reference to power, is worthy of being considered a subject for study in our schools. That educators are beginning to understand its importance, we see several indications, one of which is a new edition of Willis on Mechanism, and another and more important is this work of Prof. Warren's.

The former is not designed for a school textbook, while the latter, prepared by one of the most skilled instructors in the country, is specially designed for class work.

Prof. Warren's admirable method of classification is well applied to this new subject of scientific study.

The whole subject is divided into two portions or books. Book 1st, treating of simple or single elements of machines; Book 2d, of compound elements or sub-machines. The separate divisions of each book treat of supporters, receivers, communicators, regulators, modulators, and operators.

The slide-valve receives its full share of attention, and the elucidation afforded of its principles of action is an agreeable contrast to some of the late English works on this topic.

The work is abundantly illustrated with wood-cuts, interspersed in the text, and an atlas of folding plates.

Statistics of Mines and Mining in the States and Territories West of the Rocky Mountains. By Rossiter W. Raymond, United States Commissioner of Mining Statistics. Washington: Government Printing Office. 1870. For sale by Van Nostrand.

The second report of Commissioner Raymond is embraced in a volume of 805 pages, embellished with sections of mines and drawings of mining and dressing machinery.

The resources of the following States and Territories are given by counties, and the more important mines and mining sections are reviewed in considerable detail under the head of Part I.: California, Nevada, Oregon, Idaho, Montana, Utah and Arizona, Wyoming, Colorado, New Mexico.

The Commissioner estimates the bullion product for 1869 as follows:

California	$20,000,000
Nevada	14,000,000
Oregon and Washington	4,000,000
Idaho	7,000,000
Montana	12,000,000
Colorado and Wyoming	4,000,000
New Mexico	500,000
Arizona	1,000,000
All other sources	1,000,000
	$63,500,000

The estimated total product for 1868 was $67,000,000. "The falling off is less than the severe drought, affecting the placer mines, the disastrous conflagration in three most important silver mines, and the disturbances caused by miners' strikes in various localities could lead us to expect. In fact, the decrease in the placer product has been partly counterbalanced by an increased yield from quartz mining; and it is especially encouraging that the causes of decrease have been temporary, like a bad season in agriculture, or the accidental destruction of buildings in manufactures, while the causes of increase have been such as may be expected to operate with augmented effect hereafter. *I cannot but consider the prospects of our mining industry in the precious metals as far more promising than they were a year ago.* One phenomenon, which is almost universal, carries better augury for the future than any number of new and startling discoveries. I refer to the *reduction of wages*, and other items of hitherto unreasonable expense. This relieves mining enterprises from a burden which they have in general not been able to bear, and which has been laid upon no other industry in this country in the "same degree."

Dr. Raymond has availed himself of the services of prominent experts in the different mining sections discussed in his report, and has thus brought together a far larger and more accurate amount of information than could possibly have been obtained by personal observation with the limited time at his disposal.

Mr. Louis A. Garnett has, in a series of articles in the "Alta California," endeavored to prove Dr. Raymond's bullion estimates inaccurate. After a careful perusal of the discussions *pro* and *con*, we cannot see that Mr. Garnett proves his case. Until Government establishes some more perfect system of getting at the bullion product, all estimates must be more or less inaccurate.

In this year's report, much more attention has been given to the States and Territories other than California and Nevada, and it is most gratifying to note the rapid development in the northern Territories notwithstanding the rigors of the climate.

Colorado, although the most accessible of our mining territories, has had more disadvantages to contend with than any other of the mining sections. The disadvantages may be summed up in a few words—mining companies with bogus capital, and wild-cat property; incompetent management in the case of good property; and last, but not least, it has been *cursed with processes.*

The gullibility of Eastern capitalists engendered sharp practice on the part of the original claim owners, coupled with laziness, for it was easier to sell a claim at the East than to work it. During the years of the greatest Colorado excitement there was less gold being produced than during late years, when the production of the precious metals has been dependent almost entirely upon individual enterprise. We find the estimated yield of the precious metals for 1870 to be $4,870,000, over three-quarters of a million more than Colorado and Wyoming *together* for 1869. Another most gratifying development is that of the coal deposits, coal being turned out at the rate of 200 tons per day.

Dr. Raymond, in discussing the condition of affairs in Colorado, puts this whole matter in such an admirable manner, that we feel it our duty to quote at length, and his remarks may be well pondered by all who have or intend having anything to do with mining operations:

"The mines themselves are not to blame. I am sometimes even surprised that they have yielded so much as they have; they will prove equal to those of any other country. Mining is a business full, at best, of difficulties and risks; and it is the part of wisdom to secure at the outset as many of the chances as human foresight can perceive, or human skill control. When a man engages in this business with all the chances against him, it requires no prophet to foretell the result. Among the mines which never did pay, and never will, I unhesitatingly include those that have no existence. There have been in Colorado a great many Hamlets, with Hamlet left out. It need not be said upon what shoulders the blame should fall. Perhaps it is about equally divided. If Eastern speculators have badly burnt their fingers, some of the miners have been well plucked in their turn. It is but seldom that sympathy is required for either side. All speculation aims at getting a thing for less than it is worth, and selling it for more; and pure mining speculation—the system which looks not to the steady development of a country, but to shuffling off the burden of its development upon successive shoulders—is not deserving of success. The purchaser of stock in one of these paper companies is only anxious to raise the value of the stock and get rid of it; and often he is a fool, because he tried to be a knave and failed. It is like the 'pocket-book game' in our Eastern cities. If the stranger upon whom it is tried is a thoroughly honest man, it fails; but if he is just sharp enough to pay twenty dollars for the chance of getting a hundred out of the pocket-book, skilfully left for him to find, he falls a prey to his own acuteness and unscrupulousness, and we do not pity him when his prize turns out to be brown paper, tipped at the end with counterfeit notes."

"To the important questions, 'How came those mines, that once were profitable, to fail? What is the secret of the present success of others? How can many, now idle, be restored to an active and fruitful condition?' There are no general and universal replies. We might as well ask why one merchant fails and another succeeds. Some merchants ruin themselves by their own extravagance and incompetency; some embark in a business in which failure is a foregone conclusion, circumstances being from the outset against them. If we consider, however, the maxim, abundantly illustrated, that bad management will ruin any mine, however valuable it may be, we may say with confidence that bad management has done more to injure mining in Colorado than all other causes together. And this bad management has been fourfold in laws, in the extraction of ores, in the reduction of ores, and in general finance. Here, too, the blame must be divided. Incompetent agents have doubtless wasted money, but th y have generally acted under advice. Scientific men, so called, have made stupendous mistakes of judgment; but they have been surpassed by the blunders of practical men, so called. The scientific men without practice, and the practical men without science, the honest men without capacity, and the smart men without honesty, have done so much to destroy the mining industry in Colorado, that the very fact of its continued existence, after so terrible a trial, is proof of its inherent vitality and future prosperity. This year marks the new era of mining in Colorado. The old spirit of idleness and speculation has passed away. The new spirit of labor and economy has sprung into power. It is beginning to be recognized that the men to develop the resources of a country are the men who live in it; that the foundation of wealth is labor, and that only; that capital is only the hoarded labor of the past, loaned to the labor of the future; and that, under all, before all, above all, if there is to be progress, that must be work."

There is much of such forcible argument throughout the report.

Twenty-three pages of the report are devoted to a letter on the United States Mining Law, from the Hon. E. F. Dunne, of White Pine County, Nevada, "whose legal knowledge, as well as his long familiarity with the conditions of titles, etc., of mines on the public lands, entitle his views to the most respectful consideration."

Part III. is devoted to a consideration of mineral deposits, embracing the latest and most advanced views on this subject.

Part IV., on "The Mechanical Appliances of Mining," by W. P. Blake, is probably the most important contribution to this branch of mining industry that has ever appeared in the English language; in fact, it supplies a want that has long been felt in this country, especially by those who have had the instruction of engineers. We are glad to learn that Prof. Blake intends publishing this part separately, for the use of miners, millmen, and students. The fact of Prof. Blake editing the work is a sufficient guarantee of its excellence.

The concluding part of the report is devoted to a short consideration of the newer metallurgical processes used on the Pacific coast. We believe that Dr. Raymond purposes going into this matter very elaborately in a subsequent report.

It is to be hoped that Government will sufficiently appreciate the value of Dr. Raymond's services, to continue this great work from year to

year. The importance of yearly reports upon our mining industry is certainly not second to that of reports upon agriculture.

MODERN PRACTICE OF THE ELECTRIC TELEGRAPH. A Hand-book for Electricians and Operators. By FRANK L. POPE. Fourth edition, revised and enlarged. New York: D. Van Nostrand, 23 Murray street and 27 Warren street.

Although it is less than two years since this work was originally published, it has already become the standard treatise on American telegraphy. For this reason we are glad to see that the enterprising publisher has brought out the present edition in a style much superior to its predecessors, and with corrections and additions which largely increase the practical value of the book. Even within the comparatively short time which has elapsed since this book was first written many new facts in regard to telegraphic practice, which had hitherto escaped notice, have been brought to light by the careful investigations of such men as Farmer and Brooks. This has been noticeably the case with regard to insulation and the arrangement of batteries.

Every year's experience of our best telegraphers is leading them to the inevitable conclusion that the fundamental defect of the whole system—in fact, the root of all the innumerable evils that telegraphs are heir to, is in defective insulation. A quarter of a century has been spent in unavailing efforts to palliate or avoid its effects, while the cause itself remained comparatively untouched. Self-adjusting relays, low resistance relays, enormously heavy conducting wires, and half a hundred other devices have been successively heralded as the great specific remedy; but one by one the intelligent and thinking class of telegraphers are becoming convinced that all this is the merest empiricism and quackery. The disease itself must be rooted out. When our lines are once thoroughly and completely insulated it is an easy matter to dispose of every other difficulty that may arise. That these considerations have not escaped the notice of the author is evident from some changes which have been made in the original text, as well as the character of a portion of the new matter which has been added. Thus, on page 58 of the former editions, we read: "Experiments show that soot will destroy the surface insulation of even the best insulators, unless exposed to the cleansing action of the rain." Two years of experimenting have evidently impressed upon Mr. Pope's mind the undoubted fact that the "cleansing action of the rain" does not help the matter much, for in rain the outer surface of the insulator, though clean, is wet, and therefore a conductor, while the inside is both dirty and wet and also a conductor. He now says, "*even when exposed* to the cleansing action of the rain." An important difference, as will readily be perceived. Again, on page 63, referring to the English system of attaching earth wires to the poles, to cut off cross currents, the old editions remarked that "this practice might be adopted in this country with great advantage to the working of the line." The author has now arrived at the eminently sensible conclusion that, instead of adopting the practice referred to, "a much more economical and effective method of obtaining this result is that of improving the insulation."

Chapter IX is composed entirely of new matter, relating to "Recent Improvements in Telegraphic Practice." Considerable information is given in regard to the newly invented "compound wire," and the "gravity battery," in its different forms. This, we think, is undoubtedly destined to be the universal telegraphic battery of the future, and the author, evidently foreseeing this, has given a concise but correct description of the battery, and directions for its management, which leave little to be desired in this respect. The Siemens Galvanometer, a very recent European invention for testing the lines, etc., is well described, and its principles illustrated. This instrument has met with a remarkable degree of favor in this country, some 15 of them being already in use here with the most satisfactory results, although it is not more than a year since its first introduction. The Pope & Edison type printer, for private telegraph lines—another new and successful invention—is described and well illustrated. Nothing is said about the new Automatic system which is exciting so much interest, probably because its details are not sufficiently complete to admit of a careful description.

A very valuable chapter on "the Equipment of Lines," a much neglected point in scientific telegraphy, has been added to the Appendix, and will excite much attention and perhaps some discussion among those interested. The recommendations contained therein certainly differ very widely in many cases from present practice. The portion relating to the arrangement of sounders and registers, in connection with their batteries, is excellent. The credit of the latter investigation was due originally to Mr. Brooks, and we are glad to find that Mr. Pope has embodied it in a permanent form. "The Working Capacity of Telegraph Lines" is a treatise on insulation in disguise, and a good one, too. There is food for much study and reflection in this article.

We are glad to see Ohm's method of geometrical projection, as applied to telegraphic circuits by Webb, embodied at length in a permanent form. It is curious, interesting, and valuable, and will be better appreciated a few years hence than it is now.

A great defect in the former editions of this work was the lack of an index. This has been supplied in the present one, and it is needless to say adds greatly to its value. These additions and improvements, as well as the handsome style in which the publisher has brought out the work, will no doubt insure it a continued and increased popularity among American telegraphers.—*The Telegrapher*.

METALS, THEIR PROPERTIES AND TREATMENT. By C. L. BLOXAM, Professor of Chemistry in King's College, London; Professor of Chemistry in the Royal Military Academy, and in the Department of Artillery Studies, Woolwich. Pp. 296. (London: Longmans, Green and Co., 1870.) For sale by Van Nostrand.

This is one of the text-books of science which are being edited by Mr. T. M. Goodeve and published by Messrs. Longmans. The series is intended to supply a want that has long been felt of exact and complete works on mechanical and physical science for the use of schools, and for the self-instruction of working men. A difficulty must have been experienced by many who are engaged in teaching science, when asked to recommend a small and inexpensive text-book, which may at the same time be so simply and clearly written as

to be useful to those who have not had a scientific education, and who have not the advantage of being able to attend long courses of lectures. Many popular books on scientific subjects have been written, but they are not unfrequently somewhat inaccurate ; difficult questions being often omitted, or, what is, worse, treated in a superficial manner which is likely to mislead the student, inducing him to believe that these questions are very simple, and deluding him with the notion that he knows all about them. He is thus frequently disappointed at a subsequent period by finding that on studying the subject more minutely, it is much more complex than he at first imagined, and that many of the simple ideas which he had carefully fixed in his mind have to be discarded, and new ones acquired.

The book opens with an introductory section on the properties and treatment of metals, containing many useful tables, such as specific gravities, fusing points, conductivity, etc. The more common metals used in the arts are alone discussed so as not to introduce unnecessary complication. The remaining sections of the book treat of iron and steel, copper, tin, zinc, lead, silver, gold, mercury, platinum, palladium, antimony, bismuth, aluminium, magnesium, and cadmium. The last six being far less important than the others, are very shortly described, and only occupy 12 pages.

Each section commences with a description of the ores of the metal under consideration, their composition being given, and also the percentage of metal present. This is followed by the methods of treating the ores in order to extract the metal, chemical reactions being written in words without formulæ, so that no preliminary knowledge is necessary. The mechanical treatment of the reduced metal is then detailed, and its useful applications in the pure condition or in the form of alloys. The book is profusely illustrated with good wood-cuts, and is written in an extremely interesting manner which cannot fail to attract the attention of the student. This, together with the trustworthiness of its contents and its low price, will render the treatise extremely useful for scientific instruction. If the remaining text-books of the series possess all the advantages which are presented by this one, the thanks of teachers and students of science will be due to the editor and publishers for their undertaking.

THE YOUNG MECHANIC, a Book for Boys, containing Directions for the Use of all Kinds of Tools. Trubner & Co., London. For sale by Van Nostrand.

"The Young Mechanic" is a capital book for boys. It contains a large amount of easy and cleverly defined lessons on carpentry, joinery, tin and iron work, soldering, etc., and other subjects of a similar character, starting at the beginning, such as cutting a piece of wood with a knife (a boy's first plaything), up to the practical use of gouges, chisels, and other tools for lathes and machinery, such as are in use by adult mechanics, thus rising step by step from simple experiments to more extensive ones. The author has rendered good service to boys by producing this book, and we hope his reward will be shown by them in purchasing one each, or asking their parents to do so for them as a Christmas present or a New Year's gift. The book is well illustrated, printed in good bold type and on good paper —*Mechanics' Magazine.*

WHITAKER'S ALMANAC FOR 1871. By J. WHITAKER. London : Warwick lane, Paternoster row. For sale by Van Nostrand.

This is something more than its title indicates. It should have been "Book of Information, with Almanac." The vast amount of particulars set forth in its 300 and odd pages is beyond description. The particulars are in a condensed form, but sufficiently explicit for the purpose. We are unable to identify one page of greater value than another ; whether it relates to naval, military, commercial, scientific, statistic, or any other matter, each subject is dealt with with due regard to the interests associated with it. The usual weather and date chart is, of course, given, besides the calendars for high water, church lessons, and astronomical notes.—*Mechanics' Magazine.*

TELEGRAPH HANDBOOK. London : Lockwood & Co., Stationers' Hall Court. (Weale's Rudimentary Series, No, 138.) For sale by Van Nostrand.

"The Telegraph Handbook" is extremely handy, containing, as it does, a large amount of information relating to telegraphy. Its chief purpose appears to be to instruct persons in the official routine of the office. Copies of the usual forms for sending messages are given, and the arrangements and operations of the signalling apparatus are described with clearness, as well as the construction and mode of repairing wires and other delicate parts of the instruments. Telegraphy is becoming a trade or profession in the hands of the Post Office authorities; and the staff of female clerks they employ, and those under probation, will find this book of great value towards educating them for their duties.

MISCELLANEOUS.

A NEW CEMENT.—In the specification of a recent French patent granted to Mr. A. Warner, of London, he claims a new cement, composed in part of silicate of iron (preferably obtained from the scorious product of iron manufacture), or of oxides of iron or iron ore combined with sulphate of lime in proper proportions. To the latter, silex can be added. To give the cement the greatest durability for out-door work, Mr. Warner employs the determined proportions of the soluble phosphates, acids, or other chemical equivalents.

Practically the manufacture of this cement consists in reducing to fine powder, *laitier* (dross), or scoria, and thoroughly blending it in an ordinary flour mill with sulphate of lime, which has been mixed with a previously certain quantity of soluble phosphate. The proportions should be varied in accordance with the intended use of the cement.

The following are suggested: 700 parts calcined sulphate of lime, 200 silicate or oxide of iron, or iron ore, 2½ soluble phosphate of lime.

Superphosphate of lime may be used in place of soluble phosphate, and in this case equal quantities of superphosphate and silicate or oxide of iron must be employed. Phosphoric or boric acid may be substituted for the soluble phosphate in the proportion of 6, 10, or 14 parts (according to strength) to 300 silicate of iron. And again, any phosphoric or boric salt, or indeed any chemical equivalent capable of forming a cementing sub-

stance when combined with silicate of iron, with or without the addition of sulphate of lime, may be substituted for the phosphoric or boric acid. When the cement is made without sulphate of lime, it is well to use a larger proportion of soluble phosphate of lime.

The above mentioned substances being intimately mixed in powder, there only needs sufficient water to make the cement of the necessary consistency for the purpose.—*Le Genie Industriel de Paris, through Am. Railway Times.*

A New Danger to Ocean Cables.—The submarine cable of the International Telegraph Company, between Punta Rosa and Key West, has been so frequently broken and injured during the past year, that Col. Heiss, the superintendent of the line, determined to ascertain the cause of these accidents; and from frequent and careful examinations of the iron at the points where it was crushed or broken, he has been forced to the conclusion that the damage has been done by the loggerhead turtles which abound in these waters. In many places the cable presented an appearance which indicated the belief that it had been bitten through, and in others of having been crushed from both sides until it was flattened so as to destroy its conductivity and interrupt communication; and as the breaks and injuries have been found at the depth of water in which turtles most abound, no other cause is known to which the injuries are attributable. The conclusions of Col. Heiss are rendered the more probable by the fact that the loggerheads are noted for the great power of their jaws, with which they crush conch-shells and almost anything else which comes within their reach. This is certainly an unforeseen source of danger to which telegraph cables in tropical waters are subjected, and one for which provision will have to be made. The International Company, whose line has been so badly chewed up by the turtles, have sent an order to this city for a much larger and stronger cable, and when it is laid the turtles will have something more substantial than the present steel-wound cable to whet their teeth upon.—*Iron Age.*

Says the St. Louis "Times:" The Miss. Val. Trans. Co. has a contract with the State of Illinois to transport the iron for the dome of the new Capitol. The pieces are cast at Antwerp, transported to New Orleans, and unloaded upon the barges. Each piece weighs 10 tons, and the contract is for 10,000 tons.

The Ninth Census Complete.—The following table, prepared by the Census Bureau at Washington, gives the total population of all the States and Territories of the Union, by the enumeration of 1870, as compared with that of 1860. Several statements, purporting to give the result of the last census, have been floating through the newspapers, but this is the first that has appeared with the official sanction. It will be seen that the total population of the United States in 1870 was 38,538,180—an increase in 10 years of 7,094,859. This increase is not so much as was generally expected, but when it is considered that the great civil war of the last decade swept away several hundred thousand citizens, and that, perhaps, as many emigrants from abroad were discouraged from coming to our shores from the same cause, the country has really been doing very well. The greatest percentage of increase is in Nevada, and after it Nebraska. Two States only exhibit a decrease—Maine and New Hampshire. All the Western States show heavy percentages of increase, the Southern and Middle States a small increase, while New England is almost at a stand-still. The table is interesting and instructive:

States.	1870.	1860.	Gain. per ct.
Alabama	996,988	964,201	3.5
Arkansas	483,179	435,450	11
California	560,285	279,984	47.5
Connecticut	537,418	460,147	16.8
Delaware	125,015	112,216	11.5
Florida	187,756	140,424	38.8
Georgia	1,200,609	1,057,286	13 6
Illinois	2,539,638	1,711,951	48.4
Indiana	1,663,046	1,350,428	23.9
Iowa	1,191,802	674,913	76 6
Kansas	362,872	107,206	238.5
Kentucky	1,321,001	1,155,684	14.4
Louisiana	732,731	708,002	3.5
Maine	626,463	628,279	*.29
Maryland	780,806	687,049	13.7
Massachusetts	1,457,351	1,231,066	18 4
Michigan	1,184,296	749,113	58.1
Minnesota	435,511	172.023	153.2
Mississippi	834,170	791,302	5.5
Missouri	1,715,000	1,182,012	45.1
Nebraska	123,000	28,841	226 5
Nevada	42 491	6,857	519.7
New Hampshire	318,300	326.073	*2.4
New Jersey	905,794	672,055	34 8
New York	4,364,411	3,880.735	12.5
North Carolina	1,069,614	992,622	7 8
Ohio	2,662,214	2,339,511	13.8
Oregon	90,922	52,465	73.4
Pennsylvania	3,515,993	2,906,215	21
Rhode Island	217,356	174,620	24.5
South Carolina	728,000	703,708	3.5
Tennessee	1,257,983	1,109,801	13.4
Texas	797,500	604,215	32
Vermont	330,552	315,098	5
Virginia	1,224,830	1,219,630	.43
West Virginia	445,616	376,688	18.3
Wisconsin	1,055,167	775,881	36
Total	38,095,680	31,183,744	21.1
District of Columbia	131,706	75,089	75.5
Territories.			
Arizona	9,658	....	....
Colorado	39,706	34,277	15.9
Dakota	14,181	4,837	193.2
Idaho	14,998	....	....
Montana	20,594	....	....
New Mexico	91,852	93,516	*1 8
Utah	80,786	40,273	115.6
Washington	23,901	11,594	106 2
Wyoming	9,118	....	....
Total District and Territories	442,500	259,577	
Total of States	38,095,680	31,183,744	21.1
Total United States	38,538,180	31,443,321	22.6

—*Iron Age.*

The Belgian Iron Trade.—The iron and pig-iron trades of Belgium are feeling the adverse influence of the unexpected prolongation of the Franco-German war. New contracts remaining in suspense; prices are falling, notwithstanding the general confidence which is felt in a revival of activity on the conclusion of peace.

The use of the new Beton Coignet, for building purposes, is rapidly extending.

* Loss.

VAN NOSTRAND'S
ECLECTIC
ENGINEERING MAGAZINE.

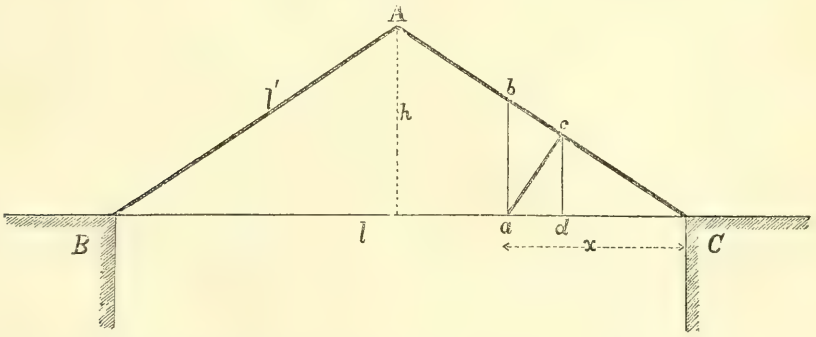
NO. XXIX.—MAY, 1871.—VOL. IV.

ROOF TRUSSES OR TRUSSED TRIANGLES.

BY S. H. SHREVE, CIVIL ENGINEER.

Trussed triangles are in common use for roofs, and may be used in many cases to advantage for bridges. They present many interesting features in the consideration of the strains affecting them from permanent and from movable loads.

FIG. 1.



Let A B and B C represent two rafters whose thrust at their supports is taken by the main tie rod B C, and which are connected with the tie rod by bracing.

Let w = weight borne by this pair of rafters.
l = distance between the walls B and C.
l' = length of one rafter.
h = height of centre of the rafters at the apex above the walls.
x = horizontal distance from one of the walls.

Disregarding for the present the braces, and taking moments around a, distant x from the right abutment, that part of the roof to the right of a is kept in equilibrium by the reaction of the right abutment, $= \frac{w}{2}$, the load on the rafter to the right of $a = \frac{w\,x}{l}$, and the longitudinal strain at b.

Hence L, the longitudinal strain, compression at b, multiplied by $a\,c$, distance from a at right angles to its direction, is equal to

$$\frac{w}{2} \times x - \frac{w\,x}{l} \times \frac{x}{2},$$

or,
$$\mathrm{L} \times (a\,b) = \frac{w\,x}{2} - \frac{w\,x^2}{2\,l}.$$

From similar triangles,

$$l' : h :: x : a\,b, \text{ or } a\,b = \frac{h\,x}{l'}.$$

Substituting this value for $a\,b$, we have

$$L\,\frac{h\,x}{l'} = \frac{w\,x}{2} - \frac{w\,x^2}{2\,l}, \text{ and } L = \frac{w\,l'}{2\,h} - \frac{w\,x\,l'}{2\,h\,l} \quad (1.)$$

When $x = 0$, $L = \frac{w\,l'}{2\,h}$, the longitudinal strain at the abutment, and as $l' : h :: L : V$, the vertical strain at the abutment, which it will be seen is $\frac{w}{2}$, or the rafter bears upon the wall with the whole vertical strain.

In equation (1) L increases as x decreases, and is greatest at the abutment and least at the ridge; at the latter place $x = \frac{l}{2}$ and

$$L = \frac{w\,l'}{2\,h} - \frac{w\,l'}{4\,h} = \frac{w\,l'}{4\,h},$$

again,

$$l : \frac{l}{2} :: \frac{w\,l'}{4\,h} : \frac{w\,l}{8\,h} = H,$$

the horizontal strain.

In the same manner, taking moments around b, we have the horizontal strain in the main tie, which is tension.

$$H \times a\,b = \frac{w\,x}{2} - \frac{w\,x^2}{2\,l},$$

and

$$\frac{l}{2} : h :: x : \frac{2\,h\,x}{l} = \text{distance } a\,b,$$

substituting

$$H\,\frac{2\,h\,x}{l} = \frac{w\,x}{2} - \frac{w\,x^2}{2\,l}, \text{ or } H = \frac{w\,l}{4\,h} - \frac{w\,x}{4\,h} \quad . \quad . \quad (2.)$$

Equation (2) is greatest when $x = 0$, or at the abutment, where it is $\frac{w\,l}{4\,h}$, counteracting the horizontal component of the strain in the rafter at the same place; when

$$x = \frac{l}{2},\ H = \frac{w\,l}{8\,h}$$

H being the horizontal strain at a,

$$H' = \frac{w\,l}{4\,h} - \frac{w\,x'}{4\,h},$$

will be the horizontal strain at a point d, distant x' from c. The strain at d is greater than the strain at a; subtracting

$$H - H' = \frac{w\,x'}{4\,h} - \frac{w\,x}{4\,h},$$

is the difference in the horizontal strains at a and d. This difference could be caused by a tie from d to b, which would add to the tension at d; or a strut from a to c which would neutralize a certain amount of tension at a. Let there be a strut from a to c. If $\frac{w\,x'}{4\,h} - \frac{w\,x}{4\,h}$ be the horizontal component of its strain, then this component will be to the vertical component as $a\,d$ is to $d\,c$.

Or

$$x' - x : \frac{2\,h\,x'}{l} :: \frac{w}{4\,h}(x' - x) : \frac{w\,x'}{2\,l},$$

the vertical component of the strain in $a\,c$.

Now consider the roof braced as in Fig. 2, it is evident that $\frac{w\,x'}{2\,l}$ is the vertical strain in any brace whose upper end is distant x' from the abutment, and that this strain increases directly as x' increases, or the vertical strain or shearing strain in the web of a triangular truss increases from the abutment to the centre. This vertical strain is the full amount of the strain in the tie from the foot of the strut to the rafter.

We have now sufficient formulæ to determine all the strains affecting a roof truss of the form shown in Fig. 2.

The weight is considered as concentrated at the points where the braces meet the rafters, and the different members of the truss are subject to longitudinal strains only.

Let A F, F L represent a pair of rafters resting on the walls at A and L; A L the main tie rod receiving the whole thrust of the rafters; the vertical braces, ties; and the inclined braces, struts.

Let w = 50 tons, whole weight, uniformly distributed.
l = 100 feet, the distance A L.
l' = 51.4 feet the length of either rafter.
h = 12 5 feet, the height of the truss at the centre, F E.
x = distances from L the wall, to the points i, h, g, f, etc.
H, L, and V, represent horizontal, longitudinal and vertical strains.

The distances between the ends of the braces on the main tie rod are equal to each other, except the parts A b and h L, which are 20 ft. in length, the others being 10 ft. each.

Equation (1) is necessary to obtain strains in the main tie rod A L, substituting,

$$H = \frac{w\,l}{4\,h} - \frac{w\,x}{4\,h} = \frac{50 \times 100}{4 \times 12.5} - \frac{50\,x}{4 \times 12\ 5} = 100 - x.$$

The first value of x is 10, whence

$$H = 90 \text{ tons},$$

the horizontal tension at i, and as the tie receives no increase nor decrease be-

tween h and L, it is the strain in h L and correspondingly in A b.

When $x = 20$,

$$H = 80 \text{ tons},$$

tension at h; and as to the left of h there is but one member subject to a horizontal strain, it gives the total strain in that member, $h\,g$, and likewise $b\,c$.

In the same manner,

Tension in $g\,f$ and $c\,d = 70$ tons.
Tension in $f\,e$ and $d\,e = 60$ tons.

Equation (2) gives the strains in the rafters; substituting,

$$L = \frac{w\,l'}{2\,h} - \frac{w\,l'\,x}{2\,h\,l} = \frac{50 \times 51.42}{2\times 12.5} - \frac{50\times 51.42\,x}{2\times 12.5\times 100} = 102.84 - 1.028\,x.$$

When $x = 10$, L = 92.56 tons, compression in K L and A B.
" $x = 20$, L = 82.27 tons, compression in I K and B C.
" $x = 30$, L = 71.99 tons, compression in H I and C D.
" $x = 40$, L = 61.70 tons, compression in G H and D E.
" $x = 50$, L = 51.49 tons, compression in F G and E F.

The vertical equation $\frac{w\,x}{2\,l}$ will give the vertical component of the compression in the inclined struts. In any strut I g, for example, as the vertical distance I h is to the length of the strut I g, so is the vertical component of the strain to the whole strain in the strut, hence from $\frac{w\,x}{2\,l}$ and this proportion,

Compression in K h and B $b = 10.31$ tons.
Compression in I g and C $c = 11.18$ "
Compression in H f and D $d = 12.5$ "
Compression in G e and E $e = 14.14$ "

The vertical strain in any rod is $\frac{w\,x}{2\,l}$, x being the horizontal distance from the abutment to the upper end of the strut from the lower end of which the tie rises.

$$V = \frac{w\,x}{2\,l} = \frac{50\,x}{200}, = \frac{x}{4},$$

When $x = 10$, V = 2.5 tons, tension in I h and C b.
" $x = 20$, V = 5. tons, tension in H g and D c.
" $x = 30$, V = 7.5 tons, tension in G f and E d.
" $x = 40$, V = 10 tons;

but as the vertical strain comes from the two struts G e and E e, F e receives a double strain, and its tension is 20 tons.

This added to the 5 tons directly on E, makes 25 tons supported by the apex.

FIG. 2.

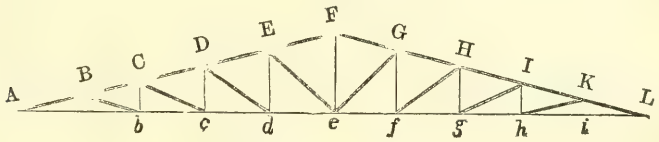


FIG. 3.

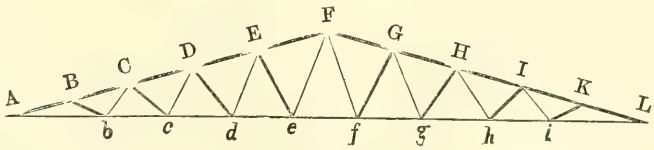


Fig. 3 is a form of roof truss also in common use, where the ties are inclined as well as the struts.

Let w, l, l', h, x, etc., have the same values and meaning as in Fig. 2, each rafter being divided into five equal parts by the braces, and in the main tie rod A b and l L are each 15 ft., and the distance between the other points is 10 ft.

The horizontal tension is found from equation (1), as before.

Tension in i L and A $b = 90$ tons.
" $h\,i$ and $b\,c = 80$ "
" $g\,h$ and $c\,d = 70$ "
" $f\,g$ and $d\,e = 60$ "
" $e\,f = 50$ "

But equation (2) does not apply without some change. The first value of x in this case is 5, and though $\frac{w\,x}{2}$ is the moment of the reaction of the abutment, $\frac{w\,x^2}{2\,l}$ is not the moment of the load on x.

Let p = half the horizontal distance from K to L, the moment of that part of the weight resting directly on the wall is $\frac{w\,p\,x}{l}$, the balance of the weight on x is $\frac{w}{l}(x-p)$; we therefore obtain

$$L\frac{h\,x}{l'} = \frac{w\,x}{2} - \left(\frac{w\,p\,x}{l} + w\frac{(x-p)}{l}(x-p)\right) = \frac{w\,x}{2} - \frac{w\,x^2}{2\,l} + \frac{w\,p^2}{2\,l},$$

$$\therefore L = \frac{w\,l'}{2\,h} - \left(\frac{w\,x\,l'}{2\,h\,l} + \frac{w\,p^2\,l'}{2\,h\,l\,x}\right),$$

Substituting constants,

$$L = 102.84 - \left(1.028\,x + \frac{25\ 7}{x}\right)$$

When $x =$ 5, L = 92 56 tons, compression in K L and A B.
" $x = 15$, L = 85.71 tons, compression in I K and B C.
" $x = 25$, L = 76.11 tons, compression in H I and C D.
" $x = 35$. L = 66.13 tons, compression in G H and D E.
" $x = 45$, L = 56.01 tons, compression in F G and E F.

The vertical strain as before is $\frac{w\,x}{2\,l}$, x being the distance from the abutment to the upper end of any strut; the tie next the strut towards the centre having the same vertical strain as the strut. The longitudinal strain can be found from its vertical component by the proportion given in the previous example. Hence we obtain

5.59 tons, compression in K *i* and B *b*.
3.53 tons, tension in I *i* and C *b*.
7.07 tons, compression in I *h* and C *c*.
6.00 tons, tension in H *h* and D *c*.
9.01 tons, compression in H *g* and D *d*.
8.39 tons, tension in G *g* and E *d*.
11.18 tons, compression in G *f* and E *e*.
10.76 tons, tension in F *f* and F *e*.

Let Fig. 2 be inverted to be used as a bridge. The members all change the character of their strains, though the amount of strain to which each is subject remains the same. The truss is now subject to the action of variable as well as constant loads, the effects of which it is necessary to examine in order to properly proportion the parts.

Let the truss be partially but more than half loaded; let the load extend from the left abutment to a point distant u from the right abutment; w the weight of a full load of uniform density with the partial load, H, L, l, l', h and x have the same meaning as in the previous cases.

By the principles of the lever, $\frac{w}{2\,l^2}(l-u)^2$ will be the vertical reaction of the right abutment. Taking moments around a point in the main suspension rod, distant x horizontally from the right abutment, x being less than u.

$$H\frac{2\,h\,x}{l} = \frac{w\,x}{2\,l^2}(l-u)^2, \text{ whence } H = \frac{w}{4\,h\,l}(l-u)^2, \quad (3.)$$

the horizontal compression in the main chord.

In this equation H is constant for the whole length of u. In the same manner for the tension in the main tie,

$$L\frac{h\,x}{l'} = \frac{w\,x}{2\,l^2}(l-u)^2 \therefore L = \frac{w\,l'}{2\,h\,l^2}(l-u)^2 \quad (4.)$$

also a constant, or the compression in the chord and the tension in the main tie are the same from the end of the partial load to the abutment. Consequently no strain comes upon the braces between the end of the load and the abutment when the partial load is more than a half load.

From a partial load equation (3.)

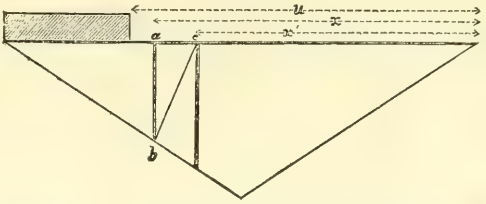
$$H = \frac{w}{4\,h\,l}(l-u)^2 = \frac{w\,l}{4\,h} - \frac{w\,u}{2\,h}\left(1 - \frac{x}{2\,l}\right),$$

as before stated, is the horizontal strain in the unloaded part. Under a full load the strain is $H = \frac{w\,l}{4\,h} - \frac{w\,x}{4\,h}$, decreasing as x increases, and is consequently least nearest the centre. Making $x = u$, we have $H = \frac{w\,l}{4\,h} - \frac{w\,u}{4\,h}$, showing plainly the strain from a full load is greater than the strain from a partial load. Similarly it may be shown that the longitudinal tension in the main tie is greatest under a full load.

The above equations (3) and (4) are true for any value of u only when x is less than $\frac{l}{2}$. That is, when the load covers less than half the truss, $H = \frac{w}{4\,h\,l}(l-u)^2$ is the horizontal strain in the chord, from the unloaded abutment to the centre; and $L = \frac{w\,l'}{2\,h\,l^2}(l-u)^2$ is the longitudinal strain in the main tie between the same points. But between the centre and the end of the load both strains change.

Let Fig. 4 represent a truss less than half loaded.

Fig. 4.



Let x again represent the distance from the right abutment to a point between the centre of the truss and the end of the load, and u the distance from the same abutment to the end of the load.

$$\frac{l}{2} : h :: l-x : \frac{2\,h\,(l-x)}{l}$$

is the vertical distance between the main tie and the chord at x, and

$$\therefore \text{H}\,\frac{2\,h\,(l-x)}{l} = \frac{w\,x^2}{2\,l^2}(l-u)^2; \text{ whence H} = \frac{w\,x\,(l-u)^2}{4\,h\,l\,(l-x)}. \quad . \quad . \quad . \quad . \quad . \quad (5.)$$

is the horizontal strain from the reaction of the right abutment, in the chord at any point between the centre and the end of the load.

At the centre, where $x = \frac{l}{2}$, equation (5) becomes equal to equation (3), and thence to the end of the load the strain increases and is greatest when $x = u$, where $\text{H} = \frac{w\,u}{4\,h\,l}(l-u)$, a strain very evidently, by comparison with equation (1), less than the strain at the same point under a full load.

The decrease in the horizontal strain could not take place unless there were ties inclined as in a full load, that is, as in Fig. 4, or struts with the opposite inclination. The less than half load, therefore, requires the same braces as the full load.

Let $\text{H} = \frac{w\,x\,(l-u)^2}{4\,h\,l\,(l-x)}$ be the compression in the upper chord at a; and

$$\text{H}' = \frac{w\,x'(l-u)^2}{4\,h\,l\,(l-x')},$$

the compression at c; then

$$\text{H} - \text{H}' = \frac{w\,(l-u)\,(x-x')}{4\,h\,(l-x)\,(l-x)}$$

is the horizontal component of the strain in $b\,c$, and this component is to the vertical component as $a\,c$ is to $a\,b$; or

$$x \quad x' : \frac{2\,h\,(l-x)}{l} :: \frac{w\,(l-u)^2\,(x-x')}{4\,h\,(l-x)\,(l-x')} : \frac{w\,(l-u)^2}{2\,l\,(l-x')} \quad (6.)$$

greatest when x' is greatest, which is when it equals u, in which case we have

$$\text{V} = \frac{w}{2\,l}(l-u) \quad . \quad . \quad . \quad . \quad (7.)$$

for the vertical strain in the bracing at the end of a less than half load.

The equation of the vertical strain under a full load at the same point is,

$$\text{V} = \frac{w\,x}{2\,l},$$

but in this case x is the distance from the left abutment or $l-u$; that is the vertical strain from the less than half load is equal to the vertical strain from the full load.

Again, $\frac{w\,(l-u)^2}{2\,l^2}$ the vertical reaction of the right abutment in the case supposed, is less than $\frac{w\,(l-u)}{2\,l}$; or the vertical strain at the end of the load, in the bracing, is greater than the vertical reaction of the right abutment.

It may be interesting to see what becomes of this excess of vertical strain between the end of the load and the centre.

In the same case and as H was determined,

$$\text{L} = \frac{w\,l'\,u}{2\,h\,l^2}(l-u),$$

the tension in the main tie rod under the end of the load,

$$l' : h :: \frac{w\,l'\,u}{2\,h\,l^2}(l-u) : \frac{w\,u}{2\,l^2}(l-u)$$

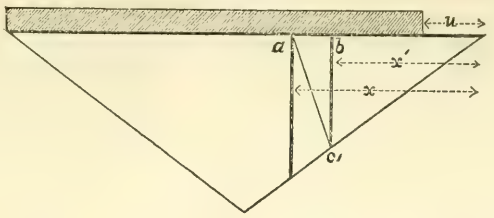
the vertical component of the longitudinal strain. This strain is passing towards the loaded end of the truss, or in the present example, towards the left abutment. Subtracting this from the vertical strain in the brace,

$$\frac{w}{2\,l}(l-u) - \frac{w\,u}{2\,l^2}(l-u) = \frac{w}{2\,l^2}(l-u)^2,$$

the reaction of the right abutment, or the excess of strain in the bracing is neutralized by an equal amount in the main tie rod.

It is next necessary to ascertain the bracing required under a partial load.

FIG. 5.



In Fig. 5, let u equal the length of the unloaded part, as before, and x the distance of any point under the load.

$$\therefore \mathrm{H}\frac{2\,h\,x}{l} = \frac{w\,x}{2\,l^2}(l-u)^2 - \frac{w}{2\,l}(x-u)^2$$

and

$$\mathrm{H} = \frac{w}{4\,h\,l}(l-u)^2 - \frac{w}{4\,h\,x}(x-u)^2 \quad . \quad . \quad (18.)$$

in which H increases as x decreases; this increase requires ties inclined as in a full load or as in Fig. 5. That is, as far as the centre, where H reaches its least value; beyond, H increases to the left abutment, requiring ties with the opposite inclination. At any other point b.

$$\mathrm{H}' = \frac{w}{4\,h\,l}(l-u)^2 - \frac{w}{4\,h\,x'}(x'-u)^2$$

$$\therefore \mathrm{H}-\mathrm{H}' = \frac{w}{4\,h\,x'}(x'-u)^2 - \frac{w}{4\,h\,x}(x-u)^2 =$$

$$-\frac{w}{4\,h}(x-x') - \frac{w\,u^2}{4\,h}\left(\frac{x-x'}{x\,x'}\right),$$

and as before,

$$x-x' : \frac{2\,h\,x'}{l} :: \frac{w}{4\,h}(x-x') - \frac{w\,u^2}{4\,h}\left(\frac{x-x'}{x\,x'}\right) : \frac{w\,x}{2\,l} - \frac{w\,u^2}{2\,l\,x}.$$

For the strains in the chord A R, compression, we have equation (2).

$$\mathrm{H} = \frac{w\,l}{4\,h} - \frac{w\,x}{4\,h}.$$

Substituting the values given above,

$$\mathrm{H} = \frac{400000\times 200}{4\times 25} - \frac{400000\,x}{4\times 25} = 800000 - 4000\,x.$$

Making x the distance from the abutment to the end of each panel, we obtain a strain passing in the same direction, but less by $\frac{w\,u^2}{2\,l\,x}$ than the vertical strain from a full load.

Hence we see that in every case the strains from the full load are the greatest, and that no braces are required for the partial load except those needed under a full load. So that equations (1) and (2) and the equation for the vertical strain are all that are needed to determine the strains and therefore make this one of the simplest forms of truss for calculation.

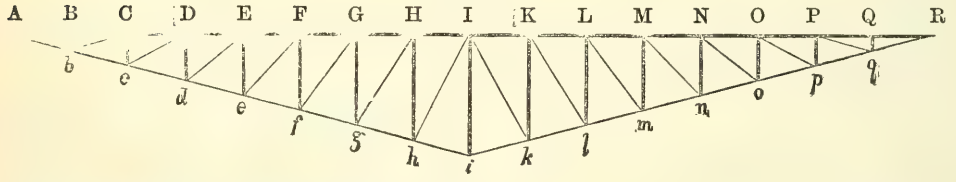
Let Fig. 6 represent a trussed triangle inverted for bridge purposes.

Let l = 200 feet, the length of the truss.
h = 20 feet, the depth at the centre.
l' = 103.1 feet, the length of the main ties.
w = 400000 lbs., the weight of the truss fully loaded.

The vertical braces are 12.5 ft. apart, horizontally.

As the strain upon each member is determined there is given with its weight, found from the valuable formulæ of Col. Merrill.

FIG. 6.



lbs.			Weight in lbs.
750,000	compression in	RQ, QP, AB and BC,	1,784 × 4 = 7,136
700,000	"	OP and CD	1,703 × 2 = 3,406
650,000	"	NO " DE.....	1,638 × 2 = 3,276
600,000	"	MN " EF	1,569 × 2 = 3,138
550,000	"	LM " FG.....	1,498 × 2 = 2,996
500,000	"	KL " GH.....	1,424 × 2 = 2,848
450,000	"	IK " HI	1,347 × 2 = 2,694
		Weight of cord.....	25,514

For the strains in the main ties we have equation (1.)

$$\mathrm{L} = \frac{w\,l'}{2\,h} - \frac{w\,l'\,x}{2\,h\,l}$$

Substituting the values given above,

$$L = \frac{400000 \times 103.1}{2 \times 25} - \frac{400000 \times 103.1x}{2 \times 25 \times 200} = 824800 - 4124\,x.$$

Whence

773250 lbs.,	tension in	q	R and	A	b.
721700 "	"	p	q "	b	c.
670150 "	"	o	p "	c	d.
618600 "	"	n	o "	d	e.
567050 "	"	m	n "	e	f.
515500 "	"	l	m "	f	g.
463950 "	"	k	l "	g	h.
412400 "	"	i	k "	h	i.

The weight of which (two ties) by Merrill's formulæ is 34,074 lbs.

$V = \frac{w\,x}{2\,l}$, is the vertical strain or the vertical component of the longitudinal strain in any inclined brace, x being the distance. Substituting the values given above,

$$V = \frac{400000\,x}{2 \times 200} = 1000\,x.$$

Whence from the proportion of the vertical to the longitudinal, we obtain,

51,520 lbs.,	tension in	P q	and	b C,	weight	184	3×2=	368.6 lbs.
55,880 "	"	O p	"	c D,	"	211	4×2=	422.8 "
62,480 "	"	N o	"	d E,	"	271.1	×2=	542.2 "
70,680 "	"	M n	"	e F,	"	380.2	×2=	760.4 "
80,160 "	"	L m	"	f G,	"	446	2×2=	892.4 "
90,120 "	"	K l	"	g H,	"	564	×2=	1,128 "
100,762 "	"	I k	"	h I,	"	705	×2=	1,410 "

Total weight of tension braces .....5,524 4 lbs.

The vertical braces are subject to the vertical strain in the diagonals next towards the nearest abutment and that part of the whole weight which comes directly upon the verticals, which in this case is 25,000 lbs., whence,

Lbs.							Lbs.
25,000	compression on	Q q	and	B b,	weight ...	21×2=	42
37,500	"	P p	"	C c,	" ...	98×2=	196
50,000	"	O o	"	D c,	" ...	243×2=	486
62,500	"	N n	"	E e,	" ...	471×2=	942
75,000	"	M m	"	F f,	" ...	796×2=	1,592
87,500	"	L l	"	G g,	" ...	1,223×2=	2,446
100,000	"	K k	"	H h,	" ...	1,804×2=	3,608
200,000	"	I i			...		3,280

Weight of vertical braces.....12,592

For the purpose of comparison, we give the strains and the weight of a Fink truss, not only to show the greater lightness of the trussed triangle, but also because they resemble each other in having a single straight chord.

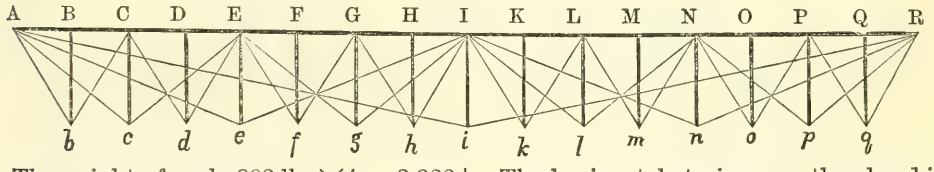
Let Fig. 7 represent a Fink truss 200 ft. in length, 18.75 ft. in depth and supporting a weight of 400,000 lbs.

The posts B b, D d, F f, H h, K k, M m, O o, and Q q, each bear the weight of one-sixteenth of the whole load, or 25,000 lbs.

The weight of each, 628 lbs.; of the eight, 5,024 lbs.

Compression on C c, G g, L l and P p= 50,000 lbs.

Fig. 7.



The weight of each, 883 lbs.×4 = 3,332 lbs.

Compression on E e and N n = 100,000 lbs.

Weight 1,313 lbs. × 2 = 2,626 lbs.

Compression on I i, 200,000 lbs., weight, 1,898 lbs.

Total weight of the posts = 12,880 lbs.

The strain on any tie is easily determined from the strain in the post to which it is attached. The latter being one half the vertical component of the former. Therefore, as the length of the post is to the length of the tie, so is half the strain on the post to the strain on the tie. Whence we have

Tension on 16 ties	15,020 lbs.,	weight	94 × 16 =	1,504 lbs.
" 8 "	41,667 "	"	362 × 8 =	2,896 "
" 4 "	142,400 "	"	2,112 × 2 =	8,448 "
" 2 "	542,613 "	"	15,335 × 2 =	30,670 "

Weight of ties.....43,518 lbs.

The horizontal strain upon the chord is uniform throughout its length and is the horizontal components of the strains in each set of ties. Its amount is 708,333 lbs.

16 pieces, weight 1,718 lbs. × 16 = 27,488 lbs.

Total weight of one Fink Truss.

Chord	27,488 lbs.
Posts	12,880 "
Ties	43,518 "
Total	83,886 lbs.

Total weight of one Trussed Triangle.

Chord	25,514 lbs.
Posts	12,592 "
Diagonal ties	5,524 "
Main ties	34,074 "
Total	77,704

A simple trussed triangle weighing 77,704 lbs. will support 6,182 lbs. more than a Fink truss weighing 83,886 lb., or the former will support 322,296 lbs. while the full load of the latter will be 316,114 lbs. And not only will it be lighter, and stronger, but it will be far more economically constructed, in practice possess many advantages, and be far more creditable to the reputation of the engineer.

SOLAR HEAT—ITS INFLUENCE ON THE EARTH'S ROTARY VELOCITY.

(*Continued from page* 341.)

Respecting the African rivers, none of which have been entered in the Tables, it may be briefly stated that they have no material influence on the earth's rotation, from the fact that the two principal rivers, the Nile and the Niger, flow in opposite directions, the former towards the pole and the latter towards the equator. There is, however, considerable difference of latitude productive of an increased retarding influence of the Nile; but this cannot be far from balanced by the greater quantity of sedimentary matter brought down by the Niger, as proved by its delta of 240 miles of coast. The general course of the other important rivers of Africa, the Senegal, Zambesi, and the Orange river, is so nearly parallel with the equator, that they exercise no appreciable influence on the axial rotation of the earth.

Australia being drained by rivers, the courses of which are directed to all points of the compass, consequently exercising no appreciable influence as regards the earth's rotary motion, has likewise been excluded from the Tables. It should be observed, that the basin of the important river Goolwa and its tributaries (excepting the Callewatta) is almost on the same parallel with the mouth of the main river; hence scarcely any retarding force is produced, notwithstanding the great extent of basin drained by the Goolwa. The Amazon, which drains more than two millions of square miles, strikingly illustrates the influence on the earth's rotary velocity of rivers the centres of whose basins are nearly on the same parallel with their outlets, the enormous mass of solid matter carried to the ocean by this river, the greatest on the globe, exerting a retarding influence of only 70,000 foot-pounds per second.

The aggregate of solid matter removed from its original position by the river systems of both hemispheres, and carried towards the equator—consequently removed to a greater distance from the axis of rotation—exerts, as shown by the Tables, a retarding influence of 39,894,658 foot-pounds per second. If we multiply this amount by 86,400 seconds, we learn that for each revolution, the earth has to overcome a retarding energy represented by 3,446,898,451,200 foot-pounds; but the effect of this retardation as regards the length of the century cannot be properly considered until we have investigated the second class of force before adverted to, viz.: that force which destroys the earth's vis viva without disturbing the position of its centre of gyration. Want of space will prevent an examination of this second class of retarding force, on the present occasion; more especially as the counteracting influence of the sediment which is carried towards the poles demands consideration. We have, however, proceeded far enough with our demonstration to prove the fallacy of the accepted doctrine of compensation relative to the energies which affect the earth's rotary velocity. We have clearly shown that constancy of rotation of the earth is incompatible with solar influence.

NOTE.—I have to state, in reply to correspondents, that the weather was not favorable for observing the maximum intensity of solar radiation on the 1st day of January. On the 7th, however, the sky was so clear as to admit of very exact actinometer observations being made. Regarding the delay, it will be proper to observe, that the distance of the earth from the sun increases only $\frac{1}{1000}$ during the first seven days after passing the perihelion, a difference too small to influence the intensity of the sun's radiant heat in a degree sufficient to affect perceptibly the indication of the thermometer. The result of

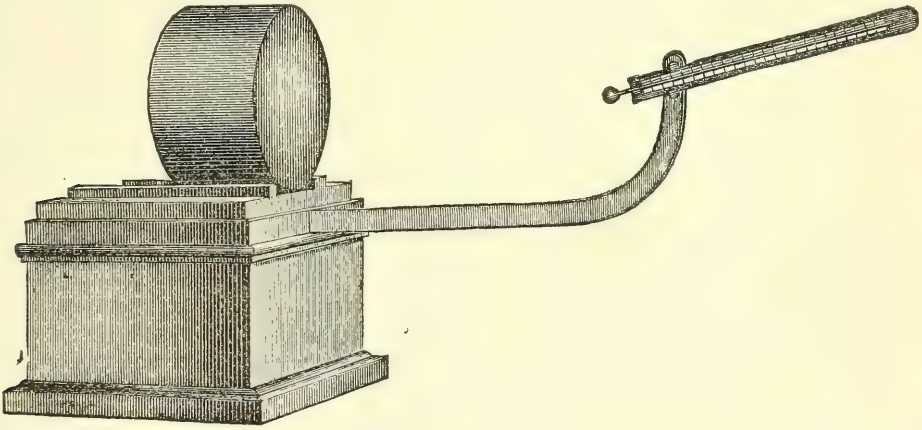
the observation of the 7th January referred to, may be thus briefly recorded: The greatest intensity 57. 25 deg. Fahr. was reached near noon, the sun's zenith distance being 63 deg. 15 min. By reference to the Table of maximum solar intensity, published in a previous article, it will be seen that for corresponding zenith distance—65 deg. 15 min.–the sun's radiant heat is 51.77 deg. when the earth passes the aphelion. Consequently, the increase of temperature at midwinter, established by the observations of the 7th January is 57.25−51.77=5.48 deg. Fahr. Agreeable to the theoretical deductions in the previous article alluded to, the maximum increase of temperature resulting from the approach of the earth toward the sun in winter. should be 5. 88 deg. The difference 0.4 deg. would no doubt have been less if the sun on the 7th had been perfectly clear. It will be safe, therefore,to assume that by means of the actinometer, we have ascertained the intensity of solar radiation with sufficient exactness for all practical purposes.

THE TEMPERATURE OF THE SUN.

By CAPTAIN JOHN ERICSSON.

From "Engineering.'

The following illustration represents a perspective view of an apparatus constructed for the purpose of proving the correctness of the indications of my solar pyrometer, described in a previous article. Objections have, not unreasonably, been raised against this instrument on account of the low temperature em-



ployed. It is contended that unless the radiator is raised to the temperature of incandescence, emitting luminous rays, the radiant heat transmitted to the focus will not furnish a true indication for determining the temperature of distant incandescent bodies. Numerous experiments, however, show that, relatively, there is no appreciable difference between the energy of the dark heat rays emanating from a metallic radiator of low temperature, presenting a thoroughly disintegrated or a blackened surface, and the energy of heat rays accompanied by a light emanating from an incandescent metallic radiator. The temperature transmitted by the radiant heat to the focus is, in each case, directly proportional to the temperature of the radiant surface. Indeed, an air thermometer placed in the focus of a concave spherical radiator of ice, and surrounded with very cold substances, say 100 deg. below zero, will furnish an indication by which the temperature of distant incandescent bodies may be ascertained with as much certainty as by employing a radiator heated to such a degree as to emit luminous rays. It scarcely needs explanation that my reason for constructing the solar pyrometer with

a radiator kept at the low temperature of boiling water, is that of admitting of operating within a vacuum, besides rendering it possible to measure the temperatures with positive exactness. No doubt the instrument might be so arranged that the metallic radiator could be maintained at a temperature considerably above that of incandescence (Sir Humphrey Davy, it will be remembered, fixed the temperature of incandescence at 812 deg.); but we lack accurate means of measuring the intensity when metals are heated to such a degree that their color somewhat resembles that of the sun, viz., white heat, or light orange. Nor would anything be gained by resorting to a mode of construction involving both complication and uncertainty, since dark heat rays, with reference to temperature, in no manner differ from heat rays accompanied by light. No irregularity has been observed in the fall of the temperature of an incandescent radiator, and that of the focal thermometer exposed to the radiant heat, while the color gradually changes from light orange to black. On the contrary, the temperatures of the radiator, and the recipient of the radiant heat, continue to bear the same relation to each other during both cooling and heating. The times, compared with the increment or diminution of intensity, differ a little; but, as stated, the proportion between the temperature of the radiant surface and that transmitted to the focus, continues as nearly uniform as experimental test can determine.

The radiator of the instrument represented by our illustration, which may appropriately be termed testing apparatus, consists of a solid cylindrical block of cast iron 10 in. diameter, 6 in. long, placed horizontally on a pedestal, the front end forming a spherical concavity of 18 in. radius, precisely like the radiator of the solar pyrometer. The underside of the cylindrical block is provided with a square projection corresponding with two guide pieces on the top of the pedestal, to facilitate the placing the block rapidly in a proper position after having been heated in an air furnace. A focal thermometer, similar to the one of the solar

Appearance of Radiator.	Temperature of Radiator.		Atmospheric Temperature.	Temperature of Focal Thermometer.	
	Actual.	Differential.		Actual.	Differential.
	Fahr. deg.	Fahr. deg.	Fahr. deg.	Fahr. deg.	Fahr. deg.
Light orange	2190	2149.3	40.7	178	137.3
Deep orange	2010	1969.3	40.7	173	132.3
Bright cherry red	1830	1789.3	40.7	166	125.3
Full cherry red	1650	1609.5	40.5	156	115.5
Dull cherry red	1470	1429.8	40.2	144	103.8
Dull red heat	1290	1249.0	41.0	130	89.0
Mean	1740	1699.37	40.63	157.83	117.2

pyrometer, is employed, held by a bent arm attached to the front side of the pedestal; the distance between the centre of the bulb and the focus of the concave spherical radiator being also precisely as in the solar pyrometer.

The accompanying Table exhibits the result of a trial of the testing apparatus under consideration, conducted at the Delamater Iron Works on the 4th Feb., 1871:

The following brief account has been deemed sufficient at present. The solid radiator, before being placed on the pedestal, was heated in an air furnace to very nearly white heat, and then, by means of tongs, quickly removed from the furnace and placed in the position shown by the illustration. The focal thermometer was then closely observed, its indication being recorded when the radiator had cooled so as to present a color of light orange. The indications during the succeeding stages of brightness and color of the incandescent radiator, described in the Table, were in like manner recorded. The temperature of the surrounding air being observed simultaneously with that of the focal thermometer. The time which elapsed between the first and last observation en-

tered in the Table was 29 minutes. It will be seen that the temperature transmitted by the radiator to the focal thermometer was recorded at six different stages of incandescence, the color presented by the radiant surface determining the time for observation. The mean temperature of the radiator during the experiment was 1740 deg., hence 928 deg. above the point of incandescence determined by Sir Humphrey Davy. Deducting the mean atmospheric temperature, 40.63 deg., the actual mean differential temperature of the radiant surface, the luminous heat rays of which acted on the focal thermometer, was 1699.37 deg. The mean temperature transmitted to the focal thermometer exposed to the radiant heat being 157.83 deg., while the atmospheric temperature, as already stated, was 40.63 deg., we find that a temperature of 117.2 deg. was imparted to the focal thermometer by a radiant intensity of 1699.37 deg. It will be recollected that in the solar pyrometer a differential radiant intensity of 163.9 deg. transmitted a temperature of 12.2 deg. to the focal thermometer; hence $\frac{12.2}{163.9} = 0.074$ of the temperature of the radiator was transmitted to its focus. In our apparatus for testing the correctness of the solar pyrometer, we have just seen that a radiant intensity of 1699.37 transmits $\frac{117.2}{1699.37} = 0.069$ of the temperature of the radiator to its focus. Consequently $0.074 - 0.069 = 0.005$ less heat, relatively, is transmitted by the *incandescent* radiator than by the comparatively cool radiator of the solar pyrometer. As this small discrepancy can readily be accounted for, the result of the instituted test fully establishes the truth of the doctrine which forms the basis of the solar pyrometer, viz., that the calorific energy of both dark and luminous heat rays is directly proportional to the temperature of the radiant surface. The cause of the discrepancy adverted to will be understood by the following explanation concerning the solar pyrometer. The heat imparted by the radiant to the recipient surface is transmitted through ether alone; hence neither the radiator nor the bulb of the focal thermometer are subjected to any loss by convection; while the incandescent radiator of the testing apparatus, as well as its focal thermometer, are exposed to the refrigerating influence of the atmospheric air. Obviously the heated bulb of the thermometer will cause an upward current of air, which, acting on its face, reduces the temperature, while the intense heat of the radiator will produce a still more powerful current. The consequent rapid succession of cold particles passing over the intensely heated surface will inevitably reduce the energy of the radiant heat, since the molecular motion within the heated mass cannot instantly restore the loss to which the molecules at the surface are continually being subjected by the cold current. The diminution of radiant energy from this cause, though not great, will be appreciable, and, added to the loss of heat, to which the bulb of the focal thermometer is subjected, satisfactorily accounts for the discrepancy of 0.005 under consideration; at the same time showing the absolute necessity of carrying on the operation within a vacuum.

Let us now calculate the temperature of the sun agreeably to the indications furnished by the incandescent radiator of the illustrated testing apparatus, without reference to the indications of the instrument, the reliability of which we are discussing. But in place of basing our calculations on the angle subtended by the sun from the earth, and the angle subtended by the concave spherical radiator from its focus, let us determine the solar temperature on the basis of *areas* and *distances* alone. Probably this method will be more satisfactory to the majority of readers than the one which takes no direct cognizance of areas and distances. Assuming the sun's diameter to be 852,584 miles, the area of the great circle will be $15{,}912{,}929 \times 10^{12}$ sq. ft. The diameter of the spherical radiator being 10 in. and the radius 18 in., its face presents 80.06 sq. in. = 0.556 sq. ft. Accordingly the sun's area is $28{,}620{,}377 \times 10^{12}$ times greater than the area of the concave face of the radiator. The mean distance between the sun and the earth is 91,430,000 miles, or 482,750,400,000 ft.; the distance between the radiator and its focus is 1.5 ft. The radiant heat of the sun, therefore, acts through a distance 321,833,600,000 times greater than the radiant heat of the incandescent radiator. We have demonstrated in previous articles that the temperature transmitted to the foci of con-

cave spherical radiators of equal area, is inversely as the square of their radii; and we have shown that, owing to the great distance of the sun, every part of his face may, without material error in our computations, be considered as equidistant from the earth. Hence, if we square and invert the before-mentioned distances through which the radiant heat acts, we ascertain that for equal intensity and *equal area*, the incandescent radiator will transmit $103,576,866 \times 10^{15}$ times higher temperature to its focus than that transmitted by the sun to the boundary of the earth's atmosphere. But the area of the sun, as we have stated, is $28,620,377 \times 10^{12}$ times greater than the area of the radiator; hence for *equal intensity* the radiant heat transmitted to the focus of the latter will be $\frac{103,576,866 \times 10^{15}}{28,620,377 \times 10^{12}} = 3618.99$ times greater than that transmitted by the sun. It will be readily seen, on reflection, that unless the temperature of the sun is 3618.99 times greater than that of the incandescent radiator, it cannot transmit to the atmospheric boundary the same temperature as that transmitted by the radiator to its focus, viz., 117.2 deg. The temperature produced by solar radiation when the earth is in aphelion, is, however, only 84.84 deg. at the said boundary; hence the sun's temperature need be only $\frac{3618\ 99 \times 84\ 84}{117.2} = 2619.25$ times greater than that of the incandescent radiator (1699.37 deg.), in order to cause an elevation of 84.84 deg. on the Fahrenheit scale at the boundary of the earth's atmosphere. Multiplying 1699.37 deg. by 2619.25, we find that the indication of the spherical radiator of our testing apparatus heated some 900 deg. above the point of incandescence, proves the sun's temperature to be 4,451,924 deg. Fahrenheit. It will be recollected that the calculations based on the indications of the solar pyrometer show that the sun's temperature is only 4,063,984 deg. The cause of this discrepancy of 0.087 has already been explained, viz., diminution of the radiant energy of the incandescent radiator, produced by currents of cold air sweeping over its face; together with the loss of heat to which the exposed bulb of the focal thermometer is subjected by the refrigerating effect of the surrounding atmosphere. Making due allowances for the loss of heat and the diminution of radiant energy referred to—inseparable from conducting the experiment in the presence of atmospheric influence—it will be found that the indications furnished by an incandescent spherical radiator, assigns precisely the same temperature to the sun as the comparatively cold radiator of the solar pyrometer. The objection urged against this instrument, that its temperature is not high enough, falls to the ground before the fact which we have established, that the intensity deduced from its indication is not affected by employing an *incandescent* radiator in place of one raised to merely boiling heat. It is specially worthy of notice that the result of the experiment with the incandescent radiator corroborates the fact established by the solar pyrometer, that while gravitating energy depends on volume multiplied by density, radiant energy depends on area multiplied by temperature; both obeying the same law in traversing space, viz., diminishing in the inverse ratio of the square of the distances.

In view of the foregoing statements and the demonstrations contained in previous articles on the subject of radiant heat, the correctness of our calculations fixing the sun's temperature at not less than 4,060,000 deg. Fahr., cannot be controverted.

An American writer gives it as his opinion that the scrap iron of thirty years ago was good, while that of the present day is very bad. The present comparative freedom from accidents attended with loss of life is attributed to the fact that the strain upon axles is not ordinarily great, and that even a very poor axle may run for a long time without showing a defect. Even an axle of wood, carefully selected, might run for years, and be infinitely safer, with the thermometer below zero, than rotten iron.

The steam ploughs used in the United States are made in England, and imported at a cost of about $10,000 in gold, each. This price, of course, includes the customs duty on the importation of machinery.

BREAKWATERS.

From "The Mechanics' Magazine."

The whole construction of breakwaters turns upon the theory of waves. If their action be not thoroughly understood and its effects provided for in a scientific and skilful manner, the strongest and most solid description of work will yield in course of time to the never-ceasing attacks of the water. A breakwater, as the name implies, is a structure designed to arrest or break the force of waves. It may be either of a temporary or permanent character, stationary or movable, and may be constructed of timber, stone, iron, and many other materials. Natural breakwaters exist in abundance, and are the results of long-continued aqueous action. They generally owe their origin to the gradual undermining of lofty cliffs by the sea. Little by little the debris accumulates until it rises above the surface of the water, and then constitutes a natural rampart, and serves as a protection against the further disintegration of the parent rock from which it sprung. Breakwaters are frequently constructed expressly for the purpose of sheltering exposed coasts and preventing the inevitable encroachments which the sea would certainly make but for the artificial precautions adopted. It is well known that whole villages have been gradually encroached upon by the sea, and ultimately engulfed. This is especially remarkable on the eastern shores of our own country.

Solid breakwaters which oppose a direct resistance to the force of the waves are during storms subjected to great violence. The maximum altitude of waves in these instances may be assumed equal to 20 ft., which exert a force upon the breakwater equal to the hydrostatic pressure of a column of water of that height. It is easy, on this assumption, to calculate the minimum thickness to be given to the stone-work. In his "Principles of Geology" Sir Charles Lyell quotes an example of the remarkable force of waves—a mass of rock, equal to 300 cubic ft., and weighing about 28 tons, was transported to a distance of nearly 90 ft. The ancients were well acquainted with the tremendous effort which waves are capable of exerting, and were in the habit of using enormous stones in their works for sea defences. Josephus mentions that Herod laid the foundations of a marine engineering work with stones containing over 4,000 cubic ft., complete monoliths, in fact. While there is, no doubt, an advantage in the size of the stones, yet it must not be forgotten that in the present day we have have attained to a degree of science and skill in construction which enables us to dispense in some measure with mere size and weight. These last-mentioned features were essential to construction in the barbarous ages; nevertheless, if there is one class of engineering works more than another in which large stones are of value, it is that connected with sea defences. When large stones are not to be procured the proper step is to bind those that are used so consistently together that they act as one mass. This was accomplished by Smeaton in the Eddystone Lighthouse. All the stones are so intimately dovetailed, joggled, dowelled, and cramped together, that it is impossible for any one to move in the slightest degree independently of its neighbors. The whole structure must yield together, if it yield at all. It cannot be destroyed in detail. It resists the forces that for more than eighty years have been incessantly endeavoring to destroy it by its entirety, and not by the strength of any of its component parts. As with a lighthouse so with a solid breakwater. The stones of the latter should be sufficiently large and sufficiently well bound together to act as one mass. Sometimes, in spite of all precautions, accidents will occur. During a tremendous storm about thirty years ago some of the largest blocks in the Plymouth breakwater were uprooted and thrown bodily into the water. They were not loose unbedded stones, but cut and squared blocks thoroughly bonded together in cement and made as solid as possible. Whatever may be the particular direction of the force of the wave, whether vertical or horizontal, or both, it is merely a question of so much weight or pressure. Obviously, therefore, a certain weight of material must be provided in order to afford an adequate resistance to the action of the water. If

this weight cannot be obtained in separate parts of the structure, that is, in each individual stone, it must be insured *en masse*. Although there is a good deal of information extant upon the altitude, weight, and pressure of waves, there is still great want of a series of accurate reliable experiments made at different times of the year and in different localities.

Having briefly noticed the solid type of breakwater, we may now glance at the other, in which, instead of the principle of direct resistance being adopted, that of the reverse is made use of. Instead of defying and withstanding the force of the waves, the other method consists in yielding to it, and allowing it to gradually spend its fury by being divided, or broken up, as it were, so that it becomes quite harmless when it arrives to landward of the breakwater. This may be effected by a stationary iron breakwater, but is infinitely better accomplished by a floating one. Patents have been taken out for floating breakwater many years ago, but as yet little or nothing has been done with them. One of the reasons, probably, is that timber was the material selected, and another that the true principle was not hit upon. The great point to be insured is the gradual but complete disintegration, so to speak, of the wave. It should be literally cut to pieces by the breakwater, and deprived of every atom of violence it possesed when first coming in contact with it. This is what is well accomplished in Saunders's breakwater, in which wrought iron is the material employed, and the necessary strength obtained by a scientific system of bracing. A great, but at the same time unfounded objection alleged against floating breakwaters is that they break away from their moorings. Many engineers of undoubted attainments share in this opinion. It is possible that they may not have seen a good design of a floating breakwater properly moored. The fact is that it is not the mooring that has to be attended to, but the design and construction of the breakwater itself. It may at first sight appear somewhat odd that if the "Great Eastern" can be held at her moorings any question could arise about holding a floating body, weighing in separate sections about 60 tons. But the cases are not analogous. A ship always rides at her anchors "end on." A floating breakwater must ride broadside on. It depends altogether on the construction, whether it can do this or not. It is needless to point out the great importance that attaches itself to the subject of floating breakwaters. Both at home and abroad there is abundant scope for them. There are, comparatively speaking, very few localities in which the large outlay required to construct a solid breakwater of masonry can be incurred. Consequently, these places are unprovided with any such protection, and it is no wonder that their trade suffers terribly in consequence. A floating breakwater supplies all the accommodation given by a fixed permanent structure at about a tenth of the cost, and can, moreover, be used temporarily at different stations, as might be required.

It is proposed to consolidate the Government lands between the Capitol and the White House, and form a fine park two miles long and half a mile wide, and lying parallel with Pennsylvania avenue, at a distance of from one to four streets from that thoroughfare. There is an intention to provide in the new park a circular drive five miles long, and to have lakes, fountains, walks, and zoological and botanical gardens, and all the appurtenances of a pleasure ground for an enlightened people.

The "Scientific American" says the area of the coal fields of the carboniferous age, lying within the limits of the United States, has been estimated at 150,000 square miles. The area of Ohio is not less than 10,000 square miles, or quite equal to that possessed by Great Britain, and far in excess of that of any other European nation. The annual coal production of Great Britain is over 100,000,000 tons; in Ohio it is now about 3,000,000 tons.

Agincourt, 28, iron-clad, Captain Beamish, at Devonport, where she is to have her defects made good, is to be fitted with Admiral Inglefield's steering apparatus, at a cost of £900.

ON THE CALCULATION OF EARTHWORK TABLES.

By GEO. B. LAKE. C. E.

The calculation of any extended table of quanties represented by an equation, is, at best, exceedingly laborious.

The well-known principle of constant differences enables one to calculate quantities with a very small part of the labor required in the method of direct substitution, and, at the same time, insures accuracy. A careful study of the results of this principle will enable us to make a still further great reduction in the required amount of labor.

Let us first notice a table of quantities represented by an equation of the first degree. Take, for example, the equation $y = \frac{1}{16} x$:

x	y	d
0	0.0000	
1	.0625	.0625
2	.1250	.0625
3	.1875	.0625
4	.2500	.0625
5	.3125	
6	.3750	
7	.4375	
8	.5000	
9	.5625	
10	.6250	
11	.6875	
12	.7500	
13	.8125	
14	.8750	
15	.9375	
16	1.0000	
17	1.0625	
18	1.1250	
19	1.1875	
20	1.2500	

By an examination of the table, we find that the last two figures of the decimal in the column containing values of y are repeated every four places. This is because the product of four into the constant difference, .0625, shows ciphers for the last two figures.

For a like reason, three figures are repeated every eight places, and four every sixteen places.

It is evident that to continue this table we have only to repeat the decimal figures already found, and increase the integral part by one at the commencement of each repetition.

Since the value of d depends on the coefficient of x, it will be easy to determine from the form of the equation the point at which the repetition of figures will commence.

A similar result will be found in tables of quantities which have the second order of differences constant.

From the equation $y = x + \frac{1}{18} x^2$ we obtain the following table:

x	y	d_1	d_2
0	0.0000		
1	1.0555	1.0555	
2	2.2222	1.1666	.1111
3	3.5000	1.2777	.1111
4	4.8888	1.3888	.1111
5	6.3888	1.5000	.1111
6	8.0000	1.6111	.1111
7	9.7222	1.7222	.1111
8	11.5555	1.8333	.1111
9	13.5000	1.9444	.1111
10	15.5555	2.0555	
11	17.7222	2.1666	
12	20.0000	2.2777	
13	22.3888	2.3888	
14	24.8888	2.5000	
15	27.5000	2.6111	
16	30.2222	2.7222	
17	33.0555	2.8333	
18	36.0000	2.9444	
19	39.0555	3.0555	
20	42.2222	3.1666	
21	45.5000	3.2777	
22	48.8888	3.3888	
23	52.3888	3.5000	
24	56.0000	3.6111	
25	59.7222	3.7222	
26	63.5555	3.8333	
27	67.5000	3.9444	
28	71.5555	4.0555	
29	75.7222		
30	80.0000		
31	84.3888		
32	88.8888		
33	93.5000		
34	98.2222		
35	103.0555		
36	108.0000		
37	113.0555		
38	118.2222		
39	123.5000		
40	128.8888		
41	134.3888		
42	140.0000		
43	145.7222		
44	151.5555		
45	157.5000		
46	163.5555		
47	169.7222		
48	176.0000		

In this table we find that the decimal figures in column d are repeated every 9 places. The reason is obvious. We find, also, that the decimal figures in column y are repeated every 18 places. This results from the following considerations: The value of y for $x = n$ is the sum of the first n terms of the series of first differences. The $(n+1)th$ term the series of first differences, equals the first term plus n times the second or constant difference. If the value of y corresponding to $x = n$ becomes an exact integer at the same time that $n \times d_2$ becomes an integer, the decimal figures will commence to repeat at that point.

It will be noticed in this table, that the decimals in column y are repeated in inverse order every 9 places. This will occur whenever a term in column d becomes an exact integer, or whenever the sum of two consecutive terms is an integer.

It is plain, that after the commencement of the repetition of figures in this or in any similar table, the decimal part of the quantities in column y may be written without further computation; and in order to be able to write the entire quantities, we have only to discover *the law of increase* of the integral portion. This is easily done. In the table we see from the value of the terms in column d., that the integral portion of the quantities in column y will, at first, increase by the regular addition of 1. This will continue until the sum of the decimal part of the quantities in column d shall become equal to or greater than a unit, in which case there is 1 *to carry*, and the integral part of the value of y is increased by 2.

And so on, until the term in column d. becomes greater than 2, after which the *regular* integral increment in column y. is 2, and this become 3 when there is 1 to carry on account of the decimal portion. We do not need to continue the series d, in order to know when to carry on account of the decimal and when to increase the regular increment; for, in general, whenever the decimal portion of the quantities passes from greater to less, there is 1 to carry; and to learn how often to increase the regular increment, divide 1 by the value of d_2. The quotient is the number of terms which it is required to know. This may also be readily learned from the form of the quantities themselves. Whenever the integral part of the series in column d is increased—that is to say, whenever the integral increment of quantities in column y is increased, it will be noticed that the decimal part of the quantities in column y will *gradually decrease* to the point where the change is made, and beyond that it will *gradually increase*.

Thus, we see that in any table similar to the one we have considered, after we have computed the quantities up to the point where a repetition of the decimal figures commences, we may continue the table to any desired length by merely *copying* the decimals in their proper order and at the same time giving the proper increment to the integral portion; and since each quantity depends for its accuracy on those which precede it, the detection of errors is almost a certainty.

It is not essential to the accuracy of the principles above stated, that the repetition of figures should include the entire decimal portion of the values of y. The value of d_2 being fractional, if a certain number of ciphers immediately succeed the decimal point, there may be the same number of decimal figures in the values of y not covered by the repetition. If, on the other hand, the value of d_2 is not fractional, there must be the same number of integral places in the value of y included in the repetition as are found in the value of d_2.

Like results might be shown in tables computed from equations of higher orders, but it is unnecessary to continue the investigation, since the equations used in the tables of Excavation and Embankment are seldom, if ever, of higher degree than the second.

NOTE.—At the bottom of page 288, March No., the quantity

$$\tfrac{1}{6}\, l\, \tfrac{1}{2}\, [r\, h_1{}^2 + \tfrac{1}{2}\, r\, h_2{}^2 + \tfrac{1}{2}\, r\, (h_1 + h_2)^2],$$

should be $\tfrac{1}{6}\, l\, [\tfrac{1}{2}\, r\, h_1{}^2 +$, etc.

At the top of page 290, the first quantity in column B should be .0648, instead of .0000, as printed.

A RIFLE tower has been erected on the upper deck of the "Lord Clyde," armor-plated screw ship, in the basin at Keyham. Communication with the lower deck is provided for by means of a scuttle inside the tower, which is placed immediately abaft the bridge.

ON PHONIC COAST FOG-SIGNALS.*

By MR. A. BEAZELEY, M. Inst. C. E.

From "The Engineer."

The coasts of these islands being liable to fogs and mists, it was surprising that the subject of fog-signals, for the guidance and warning of the mariner under such circumstances, should have received so little attention; and beyond an occasional notice or a brief suggestion among scientific journals, there were no traces of systematic research and experiment. It was by some supposed that great power and long range of sound were not essential to fog-signals, inasmuch as it was said fogs usually occurred in comparatively calm weather. This, however, was not the case, so far at least as regarded the coasts of Great Britain; for in the years 1868-69 fogs prevailed on the Yorkshire coast 51 times, at the entrance of the Bristol Channel 125 times, and near Holyhead 170 times, with a total duration of $254\frac{3}{4}$, $713\frac{3}{4}$, and $698\frac{1}{2}$ hours respectively; when the strongest winds were from the seaward, and varied in force from a mean of 4.55 and a maximum of 8 on the eastern coast, to a mean of 4.47 and a maximum of 9 on the western coast. But even where fogs were not usually attended by high winds the necessity of power and range in fog-signals was in no way diminished; for a heavy snow-storm, or thick driving sleet and rain, which often accompanied a gale of wind, were quite as blinding and bewildering as the densest fog.

In 1863 a committee of the British Association memorialized the President of the Board of Trade with a view to induce him to institute a connected series of experiments as to the effect of fog upon various sounds. It was then shown that the laws which governed the action of fogs in deadening sound were at present so imperfectly understood that such a thorough and scientific inquiry was much to be desired, and was, in fact, essential to any real addition to the knowledge of the subject; without which all investigations of isolated cases were little better than a vague groping in the dark. It was also pointed out that experiments during clear weather could not be accepted as affording satisfactory evidence of the value of any signal during fog.

The general tendency of fog to intercept or modify sound in its passage through the air, and the absence of reliable data as to the precise conditions which affected or varied the intensity of its action in this respect, had led to the suggesting whether water might not be employed as a medium for the transmission of fog-signals. The experiments of M. Colladon on the Lake of Geneva in 1826 were referred to, as well as the recommendations made in 1851 by Mr. Babbage to the United States Lighthouse Board, and Professor Hennessy's views on the same subject.

It was stated that the instruments in use for fog-signals were gongs, bells, guns, whistles, and trumpets—the two latter sounded either by steam or by condensed air, and a detailed descriptionwas given of these several appliances—whether in use or proposed—and of the experiments that had been tried to ascertain their efficacy. In conclusion it was remarked that, upon a review of the various fog-signals which had been mentioned, it was found that the whistle and the trumpet stood out prominently as regarded power and manageableness. Guns, besides their heavy working expenses, had the disadvantage of requiring a longer interval between the signals, and of entailing continuous work upon the attendant. It appeared, therefore, that it was to the improvement, and the augmentation of power of the two former, that a more efficient instrument must at present be chiefly looked for. Whatever might be the fog-signal adopted in practice, power of sound and certainty of action were indispensable conditions. Better, it has been said, no signal at all, than one that could not be relied upon; and, undoubtedly, if the mariner was led to expect a signal at a certain place, and at sufficient range to insure time to act upon its warning, it ought to be so heard with unfailing certainty. Among existing signals there were some which, in ordinary fog and moderate weather, would fulfil these requirements; but it was doubtful how far they would act to windward against a heavy gale. The howling

* Abstract of a paper read before the Institution of Civil Engineers, London.

of the wind, the groaning and creaking of the hull and spars, the shock and roar and thunder of the sea, the drenching, blinding spray, the fierce blast, the thick mist —those were the antagonists against which the fog-signal would have to try its powers ; and powerful indeed must be its voice if it afforded in time a friendly warning.

There was another point with respect to fog-signals, where in connection with a lighthouse, which ought not to be overlooked ; namely, the importance of making the character of the sounds, and their duration and intervals, correspond with the character of the light. The fixed light might be denoted by continuous sound, or better by a quick succession of sounds; the revolving and the flashing light by corresponding blasts; and colored beams alternately with white light, by a lower and a higher note alternating in a similar manner.

One difficulty in the way of employing, at rock lighthouses, any fog-signal but a bell, or such other instrument as could be sounded by the application of simple clock-work, was the unsuitableness of such buildings for the reception and working of a steam or caloric engine, and the severe labor which would be entailed upon the keepers by the use of powerful machinery worked by hand. But the author still entertained the opinion, which he formed 16 years ago, that the vast dynamical power afforded by the rise and fall of the tide would yet be utilized and applied to the compression of air for the purposes of fog-signals at such stations.

ON THE SHIP-WORM AND THE MEANS OF PREVENTING ITS RAVAGES.*

By DR. ADOLPH OTT.

From "The Engineering and Mining Journal."

The extensive destruction of submarine works caused by the teredo navalis or ship-worm, prompted the Royal Academy of Sciences in Amsterdam, in the year 1858, to appoint a committee to investigate the natural history of this singular animal, and the remedies proposed for preventing its attacks. The results of these investigations, of which we shall only present the most important ones, have now been published by E. K. von Bumhauer in the "Mededeelingen d. k. Acad. Wetensh."

The mode in which the boring mollusks —for there are several of them—perforate all bodies, from the softest wood to the hardest stone, has been the subject of various opinions ; yet, it is now generally considered by naturalists, that the rock-boring mollusks are capable of secreting a liquid which corrodes stone, while others, like pholas and teredo, bore by physical action.

As to the teredo navalis or ship-worm, it belongs to the acephalous or headless mollusks, the same zoological division as the oyster. It is enveloped by a shell and mantle, which form a sort of sheath communicating by two siphons with the exterior. The shell itself consists of two valves of equal size, which are united by a fold of the mantle in such a manner as to permit of only very slight movements. The surface of the shell, upon examination with a magnifying glass, presents a striated and indented appearance, especially towards the margins. (The wedge-like teeth present a length of 1.65 lines.) These striations are not uniformly distributed over the shell, but upon the anterior, thicker, and spoon-like part, they run nearly in a straight angle towards those of the centre. It is estimated that both valves together bear 20,000 teeth. We will remark that as long as the animal grows, new and sharper teeth are constantly formed, which substitute the older and blunt ones.

The fecundation takes place by the contact of the siphon with that of an individual of the other sex. The females, of which there are about twenty to one male, lay eggs. These are expelled in June through the siphon, and on the fourth day are already transformed into larvæ, which are capable of attacking wood.

*A paper read before the Polytechnic Club of the American Institute on the 27th Jany, 1871.

M. Kater has seen them at the end of June in large masses upon wood, and on the 15th day of July he discovered grown up mollusks in its interior.

The teredo bores at first a very small aperture in a direction perpendicular to the surface, but it changes its route after a while, in order to follow the direction of the fibres. In the first stage of its development, this imperceptible, but none the less dangerous miner has only one siphon, but later another is formed. They are of equal lengths. Both seem to serve for secreting the fæces, which mostly consist of pulverized particles of wood, forming a very fine white mass. It seems that the shorter siphon is principally used for this purpose, while the longer one serves for the reception of food, consisting of infusoria, diatomes, and other lower organisms. The bore-worm requires pure, clear water, with a certain amount of salt. If the sea-water is mingled with much fresh water, the animal dies. It continues to grow in the wood. At first the diameter of the groove is only half a millimetre, but gradually reaches five millimetres and more. The teredo itself acquires a length of from 1 ft. to 1 ft. 4 in. It usually attacks that portion of the wood lying between low and high water marks, and if it it is sometimes found above the water, it is because the timber has retained a sufficient degree of moisture. At Ostend, where the teredo abounds, it has been found in all situations below 6 ft. 3 in. (1.90 met.) above the low-water mark of spring tides.

In its abode, the margin of the mantle secretes calcareous matter and deposits it on the inner wall of the cell. This deposit is at first quite soft, but soon becomes hard. Between this calcareous layer and the animal, there is, however, left sufficient space, so as not to hinder the little miner in its movements. Strange it is, but however multiplied may be their tubes in the same piece of wood, they never mingle, so that between two tubes there is always left a partition wall, though sometimes a very thin one. "The wood," says Louis Figuier in his admirable book ("The Ocean World"), "is thus attacked at a thousand diverse points, until it is invaded and its entire substance destroyed. Submarine constructions upon which bridges are built are often riddled and perforated. They appear to all outward examination as solid and perfect as at the moment they were first erected; but they yield to the least force, bringing ruin and destruction on the edifices they support. Ships have thus been silently and secretly mined, until the planks crumbled into dust under the feet of the sailors. Others have gone down with their crews, owing to the ravages of these relentless enemies, which are horrible from their unapproachable littleness."

If removed from the salt water, the teredo dies within 24 hours, while if taken out of the wood, it continues to live in sea water for 3 or 4 days. Its abode in the ligneous tissue is therefore a condition of life. In a worm belonging to the annelidæ (lycaris fucata), which is always found in the wood excavated by the teredo, we find an enemy of the latter. This parasite attaches itself to the entrance of the tube, sucks itself to the teredo and devours it slowly. It then seeks another victim. It has a length of from 4 to 6 in., and is provided on both sides with numerous hairy feet. Behind the head, which is provided with a powerful masticatory apparatus, there are 4 pairs of tubular appendages.

Formerly, it was supposed that the naval worm was a native of the tropical zones, but the discovery of closely related species in the tertiary layers, and various discoveries of excavated pieces of timber in more recent deposits, have proved the fallacy of that supposition.

The circumstance that the teredo appeared in enormous hosts in the years 1731, 1770, 1827, 1858 and 1859, has also led to the discovery that an unusually large increase takes place whenever by lack of rain the rivers run low, thus augmenting the proportion of salt in the sea near the coasts.

For a long time past, various means have been proposed in order to preserve timber used for marine purposes from the attacks of the teredo. To gain an insight into the efficiency of these alleged remedies, the Academy of Sciences of Amsterdam instituted a series of experiments, which were conducted by Messrs W. Vrolik, P. Harting, D. Storm-Briegsing, S. W. L. von Oordt, and E. H. von Baumhauer.

In reporting these experiments, the author, Mr. E. H. von Baumhauer, calls

attention to the fact, that upon the great devastations caused by the teredo in 1858 and 1859, a number of secret remedies were offered to the Government. The scientific committee had considered it its duty not to leave any one of them untried, although there were many among them which it could be foreseen would be inefficient. And in order that no objections could be made upon the part of the members, they were allowed to conduct the trials themselves.

The experiments were made in the harbors Kissingen, Harlingen, Stavoren and Niervendam, with piles of oak, pine and fir, some of which were prepared and others left in a natural condition, so as to serve as counter-proofs. The piles were mostly $3\frac{1}{3}$ ft., long and of a cross-section of 2 to 3 sq. ft. Three classes of experiments were made :

1. The external coating, with paints and other substances.

2. The impregnation of the wood with substances by which the appearance of the surface as well as that of the interior is changed.

3. The use of very dense exotic wood.

In experiments of the first class, the following compositions were tried :

(1.) A composition of Classen, kept secret.

(2.) A metallic paint of Classen, also kept secret.

(3.) A composition of Brinkerink, consisting of Russian tallow, coal tar, rosin, sulphur and powdered glass, applied warm and after the wood had been roughed. The layer was several lines thick.

(4.) A composition of Rijhwyk, somewhat similar to No. 3.

(5.) Paraffine varnish, obtained by dry distillation of peat.

(6.) Coal tar applied cold and warm in several layers upon wood externally carbonized. Into some piles holes were bored, which were filled with hot tar and then shut, so that the tar could penetrate into the interior. Some piles were also covered with a mixture of tar and oil of vitriol, to which sal ammoniac, turpentine and olive oil had been added.

(7.) Turpentine with linseed oil paints ; among them chrome green and verdigris.

(8.) The surface of the wood was merely carbonized.

The thus prepared piles were immersed in the water at the end of May, 1859. When taken out in September of the same year, it was found that, with the exception of No. 6, none of those alleged remedies had proved effective. The timber coated with the composition No. 6 showed only traces of attacks of the teredo, but in the fall of 1860, or after one year and a half, it presented a number of excavations.

The results of these experiments convinced the committee in the most satisfactory manner that no external application furnishes protection. Although such a one may prove useful for some time, the slightest crack or abrasion, produced by the action of the water, ice, or other causes, will form an entrance for the young teredo.

It may here be well to say a word about the coating with iron nails, which although very expensive, is still largely in use. If this means is to afford protection at all, the square heads must well join together, and the piles, before being immersed, ought to be exposed to the action of the atmosphere, so that the surface of the iron may rust well and fill the spaces between the heads. And yet the Committee on Examination reports that some piles, coated in this manner, exhibited, after years, perforations of the ship-worm, although they had been covered with a layer of iron rust over an inch thick.

Concerning the sheathing of lock-gates with iron, copper, or zinc plates, a process often used, it is evident that if this covering remained complete no penetration of the wood could possibly occur. Experience, however, has shown that these plates furnish no enduring protection, owing to the fact that it is impossible to maintain an unbroken or unabrased surface. It has been discovered that nature itself affords a better protection in the case when sea-shells attach themselves to the gates before the larvæ of the teredo have had time to begin their attacks.

In experiments of the 2d class the following alleged preventives were tried :

1. Sulphate of Copper or Blue Copperas.—The piles were impregnated in Amsterdam, but it was found in the summer of 1859 that this process was unsuccessful. Yet, in order to be certain that this was really the case, the committee ordered from Paris 2 logs of beech-wood with the bark, 2 without the bark, and 2

logs of pine-wood, all of which had been saturated with a solution of sulphate of copper. These pieces also proved valueless, and the experiments only confirmed the results obtained by the engineer Noyon.*

2. Sulphate of Iron or Green Vitriol.

3, Acetate of Lead.

Impregnation with the salts yielded negative results; also,

4. Soluble Glass and Chloride of Calcium.—In order to form a silicate lime in the pores of the timber the piles were first saturated with the soluble of glass and afterwards with chloride of calcium. Before they were immersed in the water they were exposed to the air for half a year, so as to effect a perfect chemical union. In March, 1862, these piles were placed in the water, and, on examination in October of the same year, it was found that the teredo had caused great ravages.

5. Creosote Oil.—This is a product of the dry distillation of coal tar, which, by a second distillation, is purified from the most volatile as well as from the heavy oils. In the month of May, 1859, pieces of wood saturated with oil of creosote were placed at Vlissingen, Harlingen, and Stavoren, in the sea. In September of the same year they were all found free from worms, while other unimpregnated pieces, that had been placed beside them, had been thoroughly invaded. Another trial was made in July, 1860, with ten piles of oak and pine, treated with creosote ; and later, piles of beech and poplar were employed that had been treated by Boulton, in England.

All these piles were examined in the fall of 1862, '63, and '64. While those that had been left in their natural condition had been thoroughly invaded, the oak only showed traces of the worm ; but, in sawing one of the oaken piles through, the wood was found to have been very imperfectly saturated.

On investigation in the year 1864 it was found that the piles of pine, beech and poplar, treated by Boulton, in England, were perfectly sound, although exposed to the action of the teredo for 3 years ; indeed, not the least excavation could be discovered. After a layer of a certain thickness had been cut off from them they were again immersed, and proved also this time to be perfectly worm-proof.

The same satisfactory result was obtained with piles impregnated by a company in Amsterdam. They had remained in the water for 5 years. In none of this wood, not even in that which had several times been deprived of its surface layers, could a trace of the ship-worm be discovered. Of the unprepared wood that had been served as a counter-proof, nothing but the head-pieces over the water had been left ; the rest had become a spongy mass, of no strength.

In all the impregnated piles of oak there were here and there traces of the teredo, owing probably to the circumstance that the oil penetrates with difficulty into this kind of wood. It had finally been recommended to the committee to use petroleum, but, owing to its high price, no trials were made with it.

Under the third head various exotic woods, some of great hardness, were tried. However, the experiments made with them were only a few. It can only be said with certainty that some species of wood from Surinam, American oak, and several others, were not spared.

The Committee on Investigation also received a heavy piece of Guajac wood, which had been laying for five or six years in the sea at Curacoa. Being thoroughly perforated, it afforded the best proof that even the densest wood is useless for submarine constructions.

The committee finally received communications on wood reputed to be poisonous to fishes, but has had no opportunity of proving or disproving these statements. It was proposed, therefore by the Dutch Government to make inquiries in the East as well as in the West Indies.

The report of the committee sums up with the following conclusions :—1. That mere external coating of the timber with paint or other substance affords no protection ; since it is impossible to maintain an unbroken surface, the young teredo will enter the slightest crack or abrasion. The use of copper, zinc or galvanized iron plates is too expensive for most occasions ; and even these become of no use when broken. 2. Impregnating wood with soluble inorganic salts which are poisonous to animal life, furnishes no protection against the worm. This is due to the fact that the sea water soon

* Sur l'inefficacité du procédé Boucherie en eau de mer. Annales des Ponts et Chaussees, Mars et Avril.

dissolves away their strength, and that the worm does not devour or digest the wood bored out by means of the shelly jaws. 3. The hardness of the wood and its poisonous character, so far as known, are of no avail. 4. Creosote oil is so far the only substance met with that constitutes a true protection against the worm. Attention should therefore be directed to the best and quickest methods of saturating the wood with this material, and to the kinds of wood most absorbent of it. The creosote oil doubtless owes its peculiar powers in the respect just indicated mainly to the carbolic and cresylic acid it contains, and we have thus another illustration of the important applications to be made of the latter substances in our domestic and industrial economy.

Similar testimonials as to the efficacy of creosoting have from time to time been given by eminent engineers and scientists pursuing the study of applied science. In a work published in Paris in 1868, and entitled "Memoir sur la conversation des bois á la mer," Mons. A. Forestier states, for instance :

"Our studies and experiments have entirely convinced us that of all the numerous processes hitherto known, the only one thoroughly efficacious is that which consists in thoroughly impregnating wood with creosote."

In his evidence, given before the Select Committee on Harbors of Refuge, Mr. Abernethy said :

"I am convinced that timber, when creosoted, is not subject to the action of the worm, as far as my actual observation goes ; and in that case probably I am understanding it when I say it would last for half a century at least."

The earliest wood creosoted, and exposed to the sea in harbors, was at Lowestoft.

At the meeting of the Institution of Civil Engineers, Mr. T. E. Harrison remarked, that the entrance gates of the Monk-Wearmouth docks at Sunderland, which had been constructed of yellow pine, creosoted 20 years ago by Mr. Brunel, were quite sound, but portions of kyanized timber, used in the same works, had been attacked by the worm to a considerable extent.

The use of creosote oil for preserving wood was introduced in 1838 by John Bethell. In the beginning the oil was valued merely as an antiseptic, but it is now generally agreed that it is not less useful in filling the pores of the timber so as to exclude air, water, and putrescent matter.

Concerning the plans proposed for impregnating wood with creosote, we propose to briefly consider the most remarkable ones.

The Pressure Process.—The wood and liquid being contained in, and nearly filling a closed and strong iron receptacle, more liquid is pumped in till a high pressure is attained and the liquid is forced into the pores of the wood. The pressure required for the purpose approaches 200 lbs. to the sq. in., and the apparatus is consequently very heavy and very expensive. Only well-seasoned and dry wood is suitable for the process, as it is evident that if the pores of the wood be occupied with sap, no amount of simple pressure will condense the sap to permit the entrance of the preservative liquid. The great cost of setting up and working this process, and the fact that it cannot be effectively used for unseasoned lumber, have prevented its extensive introduction into the United States.

The Vapor Process.—This process was first carried out on an extensive scale by Lucken in 1811, and was revised in England by Frank Moll, in 1835, and quite recently by Mr. L. S. Robbins in the United States, who brought it before the public as a "Discovery of one of the Lost Arts of the Egyptians." This plan was proposed at a time when the value of antiseptics was overestimated, and when the necessity of sealing the pores of the ligneous tissue was overlooked. It was also supposed that by simply exposing the wood to the vapor of coal tar, a sufficient amount of the antiseptic would be carried into the pores to afford perfect protection. Leaving out of question the injury to the wood by the high heat necessary to volatilize the products employed (from 400 to 700 deg. Fahrenheit), it is evident, since the space occupied by creosote vapor is 1100 times that of the same weight of liquid creosote, no available amount can be got into the wood. And, even if it should be completely permeated, no useful end will be attained, owing to the fact, that the vapor on condensation will leave the pores empty.

The Seely Process.—The writer has

already had occasion to call attention to this process, by which, within the past three years, large quantities of railroad, dock, and pavement timber have been successfully treated. Although one of the most recent processes, it has attained a high reputation, and is already spoken of as the only one fulfilling the requirements of scientific and practical investigation.

The process, in brief, consists in subjecting the wood to a temperature above the boiling point of water and below 300 deg. while immersed in a bath of creosote oil for a sufficient length of time to expel the moisture. When the water is thus expelled, and the pores contain only steam, the hot oil is quickly replaced by a bath of cold oil, by means of which change the steam in the pores of the wood is condensed, and a vacuum is formed, into which the oil is forced by atmospheric pressure and capillary attraction. Among the advantages of this plan, the following may be named: the thorough air-drying which is required by the pressure process is obviated; the expulsion of the sap, and the amount of oil forced into the wood, is perfectly under the control of the operator; any desired fraction of the vacuum of the pores may be filled at pleasure. On examination of wood saturated by Seely's method of treatment with the microscope, the writer found every pore completely filled with oil, and this not only on the surface, but also in the centre of the piece examined.

THE NEW WROUGHT-IRON BRIDGE AT BRIDGEPORT, CT.*

This bridge crosses the Pequonnock river at an angle of about 60 deg., and comprises a total length of 845 ft. Of this length 345 ft. are taken up on the west side by an embankment between retaining walls, gradually rising with a grade of 1.66 ft. per 100. The superstructure of 420 ft., total length, consists of 3 fixed spans of 70 ft. each, and one draw-span of 210 ft. over all (centre measurements). The roadway on the permanent spans *is 30 ft. in the clear between trusses*, but is contracted at the draw-span to 23 ft., as shown on the drawing. The sidewalks on either side of the trusses are 6 ft. in the clear, except on the draw-span, where they are 5 ft. The above are unusual dimensions, but so required by the Commissioners, to accommodate a heavy and increasing traffic.

The principle of truss adopted will be at once recognized as that first recommended by Mr. Whipple, and from the fact that the posts are vertical, this system commends itself for city bridges (where trusses are unavoidable), for the reason that such posts are susceptible of more æsthetic treatment than inclined ones. The question of the appearance of such structures has too often but little consideration from engineers and town committees in these days of close competition, which is much to be regretted, for certainly an object that is so prominent in cities and towns as a bridge, observed from necessity perhaps more than any other public or private work, demands something more than simple constructive or economical considerations.

The trusses of the permanent spans are 5 ft. $8\frac{3}{4}$ in. deep, and are broken up into 12 rectangular panels. Each upper chord is 19 in. wide, and is composed of varying thicknesses of boiler-plate riveted to two 6-in. rolled channel bars and one 6-in. flanged beam. The lower chord is formed from weldless links, whose heads have been made by upsetting. These links, the length of one panel, are joined by carefully turned pins, which pins also form the connection for the diagonal braces and posts. The braces are also links, formed as above, the connection with the upper chord being by means of a pin passing through the channel bars.

The vertical posts are in pairs, and are the patent wrought-iron column of the Phœnix Iron Company. They are formed by riveting together 4 segments of a true cylinder by means of flanges which are turned outward. Cast-iron caps and bases, turned and fitted, form the bearings between the chords. It should be remarked, in connection with the braces, that the counter rods have turn-buckles upon them, forming the only adjustable feature in the truss. The floor-girders

* From a paper read before the American Society of Civil Engineers, by ALFRED P. BOLLER, C. E., Member of the Society.

(of which there are 3 in each span) are trussed $2\frac{1}{2}$ ft. deep, as shown on drawing, and have their bearing upon the base castings through the medium of projecting brackets. The upper member consists of two 6-in. channel bars, passing either side of posts with a plate 10 in. wide riveted on top. The channel bars project beyond the trusses to support sidewalks. Horizontal sway braces, intersecting in a ring, are attached to the floor-girders at their bearing points on the trusses. The 3-in. spruce planking which forms the roadway is supported upon longitudinal stringers of 4×12 white pine placed 18 in. apart. The sidewalks are planed yellow pine plank 2 in. thick. The railing is of simple but effective construction, and made from two very light tee bars with diagonal strips riveted to the webs. The diagonals intersect in a cast-iron boss, and the top rail is finished off with a half round strip riveted upon it.

The draw-span, at present the largest self-sustaining draw in the Eastern States, is supported upon a Parry-anti-friction pivot and a circular drum 28 ft. diameter, of wrought and cast-iron, bearing upon chilled wheels in a live ring. At intervals heavy diagonal rods connect the bottom flange of the drum with the pivot, while light counters run in the opposite direction, as shown on the drawing. There are six points of contact between the turn-table and bridge, the middle contact being made by means of a heavy cross-girder.

The trusses of this span are placed 23 ft. 6 in. apart, centre to centre, and from the depth of the permanent spans at the free ends rise in an easy curve to a depth of 12 ft. 3 in. at centre. An important saving of material would have resulted from an increased central depth, but the Commissioners desired, if possible, that the trusses should not be carried so high as to necessitate horizontal connection between the top chords. It may be remarked, also, that the height adopted allowed of a curve in more pleasing proportion to the depth of the fixed spans. Owing to this arrangement, it was deemed desirable to form the top chord of weldless links, the voids between adjacent links being filled in with packing pieces, wedged in place with keys. In addition to this, the two separate lines of links on either side of posts were further stiffened laterally by means of light castings.

The usual riveted arrangement of a top chord for such purposes would have required a large excess of metal, for self-evident constructive reasons.

The lower chord of either truss is composed of four 9-in. channel bars, of increasing weight from end to centre. These bars are strongly braced together, and their continuity is assured by splice-plates and rivets. The posts are in pairs, as in the fixed spans, and are also wrought-iron columns.

They are placed for 9 panels, 10 ft. 8 in. apart, while the first panel on either side of centre post is 7 ft. 6 in. long. The centre post over pivot is a single one for each truss, and is compounded from four 6-in channel bars and 4 segments of a cylinder, riveted together by means of their flanges.

The diagonals are square bars, with upset screw ends bearing against angle blocks, fitting between shoulder plates riveted to under side of lower chord.

The cross girders at every other panel are single-trussed beams instead of double, as in the case of the fixed spans. The base castings of the end posts have a circular track bolted to them, composed of two 6-in channel bars, back to back. The bearing is upon wheels bolted to the masonry, and upon which the above track runs as the draw is open or shut. A self-acting, vertical latch secures the draw in position when closed for traffic, and is opened by means of a lever, operated at centre of bridge. A compound gear is arranged on the drum in case a heavy wind is blowing, or to ease the bridge tender in starting the bridge from its bearings after a long period of quiescence.

The following data in regard to "weights" will prove of value in this connection :

First.—Permanent span.

Average weight of iron per foot	620 lbs.	
Average weight of timber railing	710 "	
		1,330 lbs.

Second.—Draw span.

Average weight of iron per foot	1028 lbs.	
Average weight of timber railing	575 "	
		1,603 lbs.
Turn-table and appliances	85,000 "	

In the presence of the city authorities and parties interested in this work, a careful test was made by means of pig iron, with which the bridge was loaded up to one ton to the foot. Under this load the permanent spans deflected $\frac{7}{16}$ths of an inch, which was recovered when the load was removed. The draw was only loaded half its length, the result being a deflection of $\frac{9}{16}$ths of an inch, which was recovered before half the load had been removed.

Had the draw been loaded over its *whole* length instead of half its length, with a ton to the foot, the result would have been still more satisfactory. The deflection on either side would probably have been but little over half of what was exhibited. The result of these severe tests is regarded as eminently satisfactory. Although more attention has been given to æsthetical considerations than is usual in such work, much more could have been accomplished had the expenditure been authorized. As it stands, the bridge is painted a pleasing monotone of light yellow ochre, the effect of which would have been very much heightened by picking out the mouldings, bolt-heads, and other salient points, with an Indian or brownish red. This I trust will be done by the city authorities when the bridge requires re-painting.

It may be of interest to note the fact that *all* tension members in the main trusses were tested up to 20,000 lbs. per sq. in., which strain they were required to stand without a permanent set.

NAVIGATION OF THE GULF OF MANAAR.

From ' The Engineer."

The success that has attended the efforts of M. De Lesseps to unite the waters of the Mediterranean and those of the Arabian Gulf, has had the effect of giving a stimulus to numerous undertakings similar in kind. Whatever geologists and geographers may think about the matter, engineers and capitalists are rapidly ariving at the conclusion that an isthmus has no business on the face of the earth, or on the map either. It is true that it may form the immediate link between continents or continents and their adjoining islands, but at the same time it constitutes an impassable barrier for ships proceeding to distant countries on either side of it. At the present day it is not sufficient to have two countries in connection, but they must be separated as well. The problem is solved by cutting through the isthmus in the first place, and bridging over the cutting in the second. A canal must run across the tongue of land to provide for the water traffic, and a bridge must be thrown over the canal for the transport of the land traffic. Thus native and foreign intercommunication will be established, and there will be at once a connection and a severance. That which has been accomplished on comparatively a small scale with our own railways and canals will have to be effected far more extensively, and with greater pretensions to magnitude, before some of the projects for severing the natural features of the globe arrive at a practical realization. The proposed piercing of the Isthmus of Darien is an old story, and from the last accounts not a whit nearer the desired stage than when it was originated. The discovery of the indispensable cañon, or gorge, through which the waters of the mingled oceans are to flow, is not the certainty that has been predicted, although it has been stated by some to be actually in existence. Similarly, the scheme for uniting the Archipelago with the Adriatic has not yet got beyond that preliminary state which, while it promises everything, accomplishes nothing. Were Venice still the emporium of Europe, were she still the Queen of the Adriatic, as she once was, there might be a hope that her interests would conduce to the severing of the Corinthian isthmus. But, as it is, the undertaking would not benefit—at least not for some time—the giant nations of the world. It would not connect two oceans, but simply a couple of inland seas, and it is questionable whether in the present state of Greece there is sufficient traffic to make the speculation remunerative.

But let the trade of the country be once developed, as it ultimately must

be, and the isthmus will be erased from the map.

Among other schemes of this character which have lain in abeyance for some years, but which appear to have been drawn forth from the apparent oblivion to which they were consigned by the event alluded to at the commencement of our article, is one which very materially affects our trade with India. It is nearly 9 years since the question was entertained by Parliament, and a committee appointed to inquire into the scheme of cutting through an island in the Gulf of Manaar, so as considerably to abridge the length of the voyage to Calcutta for deep-sea-going vessels. A glance at the geographical features of the proposed work will be of assistance in arriving at a clear comprehension of the value of it with respect to our oriental traffic. The main land of India, near its southern extremity, is severed from the shores of the adjoining island, Ceylon, by Palk Straits. In the narrowest part of the channel which intervenes between the Gulf of Manaar and Palk Straits there are one or two islands and a long shoal about midway, called by the ancient name of Adam's Bridge. This channel, which extends from Shoondradasy on the mainland to Mantotte in Ceylon, is navigable for vessels of a certain draught only, so that for others exceeding this amount it forms in reality an isthmus. The project has now been revived, and attention has again been drawn in Parliament to the necessity of piercing through the intervening promontory, and thus opening up a direct through route to the long stretch of the Coromandel coast and the Gulf of Bengal. It is estimated that the saving in distance alone for vessels bound to Calcutta would amount to 730 miles. In addition to this important advantage the place of call would be shifted from a situation where there is little or nothing in the way of refreshments for the crews and passengers of ships, to one which abounds in provisions of all descriptions, exceedingly well adapted for the consumption of voyages. It appears that, imperfect as the existing passage is, the ships which are able to navigate it have increased in numbers to such an extent that they now carry 200,000 tons instead of 7,000, which composed the whole of the traffic 40 years ago. This is quite sufficient to indicate that, were increased facilities for navigation afforded between Ceylon and the mainland, there would undoubtedly be a considerable augmentation in the annual tonnage of freight. The value of the new route would probably be enhanced in the course of time, when sailing vessels give place to steamers—a contingency that must happen sooner or later to all ocean-going ships.

When a project of the kind is mooted the first point to be settled is the party upon whom should devolve the construction of the work. In the present instance it has been broadly stated that the Indian Goverment ought to take the matter in hand, as the site of the proposed undertaking lies within their territory and jurisdiction, and moreover the result of the scheme would tend most unmistakably to the advantage of their dependencies. On the other hand, the Indian Government have many large and important works already in progress, which tax to the utmost their resources, and they in consequence do not feel themselves at liberty to commence others which are not so immediately connected with the country as those they are now engaged in. Is the work to be done by Government or by a company? As the former do not seem inclined to move in the matter, it may be presumed that if the work is done at all, it must be by the same means by which so many great engineering projects have been carried out, namely by private enterprise. Assuming this to be the case, the next consideration is, what will it cost and what return is it likely to yield on the capital expended? As to the prospective benefit that the opening of the channel will confer upon European or Indian traffic, that is a matter which in the abstract does not concern a company. Their only inducement to undertake the execution of the work is the probability of its eventually proving a remunerative concern. The cost of the entire work has been estimated at about £90,000; let us put it at £100,000. This sum is a mere trifle when weighed in the balance with the expenditure upon some of our home contracts. We are so accustomed now to deal in millions that anything below 1,000,000 is thought nothing of. There could not be the slightest difficulty in raising so small an

amount provided capitalists were tolerably certain of the financial success of the speculation. How then is the paying part of the undertaking to be provided for? In a manner similar to that which insures an annual revenue to the proprietors of the Suez Canal. All ships drawing more than a certain draught of water, which are now compelled to circumnavigate the island of Ceylon, would, in the event of the new route being opened, be able to pass through the channel and thus save over 700 miles in their voyage to and from Calcutta and other places situated in the Gulf of Bengal. For this considerable reduction in the length of their voyage they would be willing to make some return in the shape of a toll, and there is very little reason to doubt that, considering the comparatively insignificant amount of the capital required, the whole of the tolls would suffice to pay a very handsome profit. Experience has invariably shown that increased facility for traffic, whether of goods or passengers, is always attended with a commensurate increase in the traffic itself. They mutually act and react upon one another. The deep water channel cut through Adam's Bridge would very much exceed in lateral dimensions the Suez Canal. Indeed, it is now well known that it is only a question of time and money when the latter is to be both deepened and widened. The first great object to be accomplished was to prove that a navigable canal could be cut from one shore to the other. That being now satisfactorily demonstrated, the affair can be taken in hand and completed in the manner so great a work fully deserves. No means should be spared, whether the agent is the Government or a company, to reduce to a minimum the length of the voyage from our shores to those of India. The piercing of the Isthmus of Suez is the first step, and the cutting through of Adam's Bridge ought to be the second.

BROKEN TYRES.

From "The Mechanics' Magazine."

Next to fires, the easiest forms of disaster to classify are railway accidents, certain seasons almost invariably bringing particular descriptions of misfortune. The excursion season has its set, foggy weather is responsible for a share, and last but not least, severely frosty weather adds no inconsiderable quota to the list for any given year. Men of science, be they doctors or engineers, differ in their views, and it is only of late years that the members of the latter profession are becoming at all unanimous on the subject of the influence for evil exerted by hard frost on railway tyres. The arguments of those who denied the practical effect of any but extreme temperatures were based on the fact that iron had its tensile strength but little affected by ordinary winter frost in this country, so far as special experiments with testing machines were concerned. Facts, however, are stubborn things, and it is vain to say that frost cannot be the cause so long as tyres and axles break more frequently in cold than in warm weather. A little investigation, too, will go to show that experiment and practice, in the real sense of the terms, do not materially differ in results. It is one thing to suspend a bar of iron with a given load attached thereto, the thermometer recording so many degrees of frost, and quite another to set a railway wheel in rapid motion over a rail. In fact, the whole nature of the relative conditions are essentially different. To begin with, the strain of the tyre from tension is almost unknown in magnitude. No two tyres are shrunk on with the same amount of tension; no two are precisely alike in their chemical constituents. Again, a large allowance must be made for the influence of a frosty road; the metals during a severe frost have no particle of elasticity, and here is a source of fracture. To gain an idea of the different aspects of the question in frosty, and in summer or damp weather, we should suspend two rods and strike the one with an iron bar and the other with a bar of lancewood, or, better still, with a bar of whalebone. We find Russian and American engineers ready enough to acknowledge the effects of severe climates on their rolling stock, but really, when we come to examine the question, we find that it contains room for much

more investigation than it has yet received. For example, what do we know of the influence exercised by various forms of springs on the durability of tyres? To take a goods truck and a first class carriage would be but an imperfect comparison, because of the different nature and conditions of their work. One-half of its running time, a goods wagon wheel is loaded to its full amount, the rest of its time it is running comparatively idle; as a rule, too, its speeds are lower than those of the carriage. The single fact that the two vehicles afforded examples of the best and the worst forms of springs would not be enough. Another point again that might well be investigated is the influence exercised by different methods of construction of wheels on the durability of the tyres. Were we to have these sorts of accidents oftener, the influence of temperature would possibly be better examined into, and yet, even as it is, and setting aside the matter of life and limb safety, the question is one of interest from the abstractedly scientific point of view. Metallurgists well know that the presence of phosphorus in ever so minute a quantity will render iron cold short, so much so, indeed, that a smart blow will break a bar containing any without any question of fatigue of metal being involved at all. It is quite reasonable to suppose that, if a certain proportion of phosphorus render iron cold short where the difference of temperature lies between melting or welding point and ordinary weather temperature, a different proportion may have influence when the temperature is greatly reduced. That, however theorists may deny the influence of cold on wheel tyres or axles, railway companies are believers in it, we may gather from the fact that during severe weather the speed of fast trains is diminished. It is a pity that there is no published register of the lives of tyres and axles, with a statement of the methods of construction, the speeds, and the nature of the work each has been called upon to perform. Wheels which have wood interposed between the tyre and the axle ought to be more durable and less liable to fracture than those without an elastic medium between the two, yet we have no record of the relative number of broken tyres on the two types of wheel. Railway companies probably keep some such register to a certain extent for their own information, but we fancy it must be but an imperfect one. We wonder why the same plan of hooping railway wheels has not been adopted as that used for securing the rims of artillery wheels. There is no necessity whatever that railway wheel tyres should work in a constant state of tension. The duties of a tyre on a cart would consist in keeping the felloes together and on the spokes, but a rail tyre has not such duty to perform. In point of fact, the tread of the wheel should have no duty whatever to perform, but to take the wear of rolling on the rail and nothing else. Railway wheels, even to this day, are made too much on the principle of common wood wagon wheels, while the relative structures of the two types of wheel have nothing else in common. It may very reasonably be asked why is a railway wheel tyre shrunk on at all? Not to force the parts of the wheel together, as in the wood wheel; not to secure the tyre itself in its place, because it has no reliable effect of the kind. To what other purpose, then? To none but the evil one of putting the tyre in a constant fatiguing state of tension, injurious to the metal of the tyre, without any compensating beneficial effect. Many ways are to be found of constructing a wheel that will sustain a load without any hoop, and on this a hoop could be so secured as to form, not a circular girder, but simply a wear and tear band, which could be removed without difficulty. Why should not a wheel with rim, spokes and flanch complete, be forged in one solid piece, and afterwards a thin steel hoop be placed on the tread of the wheel, and secured with a few rivets; this could be taken off when worn and a fresh one put on; this, too, could be effected without the cost of turning the tyres on the wheels in the lathe, as they could be turned and bored true, and the wheels being turned true also when first made, the rim could be put on and riveted. Even did this outer hoop give way, there would be little chance of the train getting off the rails, as the wheel itself with its flange would be capable of bringing the train in safety to a station. The great evil of engineering is the proneness of its disciples to travel in a groove—to copy, or to adopt old cloth to the new garment. It is true that experiments are inadmissible where human life is concerned, but

experiments can be carried out with goods rolling stock at first, and afterwards with passenger carriages. From the pecuniary aspect, the question is worth dealing with, on account of the heavy bills for compensation paid by companies. There is one point that might perhaps prove objectionable to the thin tyre plan. The rolling action on the rail tends to stretch the tyre, and thereby enlarge its diameter, and thus loosen the hoop, but the question could alone be determined by actual experiment.

The use of wood in wheel construction has increased of late years, and few fast trains are made up now with any other style of wheel. Indeed, the idea of hooping a rigid iron wheel which is called on to endure much hard work of a concussive nature, with a band shrunk on, appears rather an unscientific proceeding. Tyres fail both from the fatigue of constant tension and concussion, and also from the strains caused by difference of speed between the two wheels on one axle in passing round sharp curves. Any means whereby loss of life and property from broken tyres is prevented is well worth the cost of a few experiments, and the increased immunity from accident and its attendant expenses would well repay the first outlay.

PURIFICATION OF PIG IRON.

From "Engineering."

There is one great and all-important problem which stands out prominently before the mind of every modern metallurgist as the next grand step to be taken in the practical manufacture of iron and steel—a problem, which in spite of all the power that has been brought to bear upon it during the last 10 years of gradual and extensive progress remains at the present moment unchanged in its stubborn resistance to science and skill, unsolved and apparently unapproachable by any of the appliances with which science has as yet furnished the practical metallurgist of the present day. The chemical differences between the highest classes of iron selected for the production of the best steel and the commonest brands of pigs, which are known in the market, consist in minute proportions of sulphur, phosphorus, and silicon, which are held in combination by inferior iron, while the absence of these elements is the characteristic of the high class material. The removal of these minute doses of foreign matter would have the effect, therefore, of abolishing all differences in quality, and consequently in value of the different brands of iron which are now collected from all parts of the world for the purpose of supplying the varied demands of iron and steel manufacturers ; while, the quality of iron and its products being improved, there would result an extraordinary benefit to the iron industry at large. It is obvious, however, that all that can be gained by a successful process for purifying pig iron is to bring up the value of the inferior qualities of pig iron to that commanded by the pigs of superior purity ; and therefore a process, in order to be practically useful, must not exceed in its cost the average difference which exists in the market between the prices of the highest class and the commoner classes of pig iron. This important point has proved the stumbling-block for several more or less ingenious inventors, who by their failures have pointed out more clearly thanwas before visible in what direction the road to progress did *not* lie. The removal of sulphur, phosphorus, and silicon from iron may be attempted in three different stages of manufacture, viz., the treatment of the iron ore, the refining of pig iron, and the process of manufacturing malleable iron or steel. The chronological order in which such attempts have been principally made follows the inverted course from that indicated above. The first efforts to purify iron were entirely confined to the process of conversion into malleable iron, and they have been so far successful as to master the difficulty in a more practical manner than any of the subsequent inventions have done. The silicon is entirely disposed of by the charcoal finery, and nearly so by the puddling process ; a proportion of sulphur, and particularly a considerable proportion of phosphorus, are eliminated in the process of puddling and balling. With this,

however, ends the record of success as yet obtained in that direction. The action of the puddling furnace seemed to require some further assistance or stimulant for the removal of the noxious element, and consequently an innumerable host of ingredients have been proposed and tried in succession for effecting this desired end. Only a few of these attempts have had a sufficiency of scientific plausibility to deserve notice, but even these have not maintained themselves in practice. The powder composed by Schafhanth, consisting of common salt and oxide of manganese, was one of the most popular compositions of the kind ; its action was supposed to be due to the chlorine and the sodium in a nascent state. Next came the litharge, or oxide of lead process, relying upon the affinity of lead for sulphur and phosphorus at a high temperature. After the invention of the Bessemer process, hydrogen, chlorine, and carburetted hydrogen were tried in succession and blown through the converter, but without any favorable result. The Heaton process effected the purification by means of nitrates, but it proved, however, too expensive for commercial work. Mr. Bessemer at one time expressed an opinion that the removal of some noxious elements might be effected in the converter if the decarburization could be so protracted as to give a sufficient time to the other elements to combine with the oxygen of the blast. With a view to produce this result, the employment of hydro-carbons, naphtha, charcoal powder, graphite, and other carbonaceous matter, was tried in the Bessemer process, but no good resulted from all these experiments. M. Berard proposed to use the carburizing influence of a flame overcharged with gas in a Siemens furnace, for the purpose of keeping his bath of pig iron under the action of his process for a protracted period ; but M. Berard did not succeed in practically working out his ideas.

Inventors next turned to the refining process as a preliminary for the manufacture of malleable iron and attacked the impurities in that stage of the process of manufacture. Mr. Palmer Budd runs his pig iron over beds composed of oxide of iron and of nitrates ; M.Ellershausen mixes the pig and the oxide of iron into the form of sandwich cakes ; but from all this applied ingenuity there has resulted nothing of value for metallurgical practice.

At the present moment, two inventions for purifying iron ore are prominently before the public, and awaiting their trial in practice. The one is the process of Mr. J. E. Sherman,of which some accounts have already appeared in our columns, but upon which the evidence is not as yet completed. It has in its favor some decidedly important results, vouched for by the firm of the Atlas Works, and therefore readily accepted as facts, but it has against it the contradiction in which it stands to all accepted theory and chemical knowledge. A rival invention to that of Mr. Sherman is that of Mr. James Henderson of New York. This latter consists in the simultaneous application of fluorine and oxygen, and it has, at least, no theoretical improbability upon the face of it. Mr. Henderson employs fluor spar mixed with titaniferous iron ore, or with oxide of iron, either in the refining process, or in the puddling or steel-melting furnace. The effect of fluor spar upon pig iron containing phosphorus was tried repeatedly before this, but the result was negative. It does not from this follow that the effect of a combination of fluor spar with titaniferous iron ore, or with oxide of iron, will be equally ineffective, and it appears at least worth a trial, whether the process proposed by Mr. James Henderson has the germs of a final practical success in it or not. Both fluor spar and titaniferous iron ore are sufficiently cheap and abundant to permit of their being freely used for such a purpose, and the results if obtained by so simple a process, would be well worth trying for in this country at the present moment.

A new steam dredge has been launched from the foundry of Messrs. V. & D. Coates, Belfast. It is one of the finest in the country, and will be used in clearing the harbor and lough. It is of iron, 120 ft. in length, 24 ft. beam, worked by one pair of horizontal condensing engines ; has 35 buckets, each capable of lifting 8 cwt. of sand.

The Brooklyn Pier of the East River Bridge will soon appear above the surrounding buildings.

FERRIE'S BLAST FURNACE.

From "The Scotsman," Scotland.

The following is a description of Mr. William Ferrie's blast furnace, which, 4 months ago, was lit up at the Monkland Iron-Works, Calderbank, near Glasgow. The furnace, we learn, is constructed on the bell and cone principle, neither flame nor smoke being allowed to escape at the top of the furnace. The coal is self-coked in 4 descending compartments or retorts, and the heat necessary for this purpose is created by the burning of the waste gases in a series of flues arranged around the retorts. In addition to an ample supply of gas obtained by the destruction of coal during the process of reduction and employed for the self-coking of the coal, an enormous surplus is given off, and, as we shall see by and by, is utilized in other departments of the work. Not only is there a sufficiency of gas to sustain a temperature ranging from 1,400 deg. to 1,700 deg. Fahr. in the flues, but a capacious pipe leads off a surplus to a distance of several hundred feet. From this main pipe gas is withdrawn to supply the heaters of other three furnaces, and this, too, in addition to supplying the heaters connected with the patent furnace, maintaining a heat higher and more regular than could ever be obtained by the employment of dross. This gas leaves the furnace at such a temperature as to render it highly and easily combustible. As to tar and other effete material supposed to be created during the operation of this furnace, it has been found not to exist. It is only in the situation of the valves connected with the main pipe, where the permeating gas comes incidentally in contact with the atmosphere, and becomes condensed, that any appearance of tar is found to exist, and then only to a trifling extent. This can easily be accounted for, from the fact that the gas is driven off in such a state of dryness as to prevent all likelihood of this occurring, so that the tar is volatilized along with the other volatile constituents of the coal, the temperature at this point being about 500 deg. Fahr. What economic value is obtained from the Ferrie furnace? What are its advantages over the ordinarily constructed furnaces in use throughout Scotland? The ordinary hot blast furnace requires for the production of every ton of pig iron 50 cwt. of coal; whereas by this new process it is an ascertained fact that 34 to 36 cwt. of coal will produce a ton of rich No. 1 iron, thereby effecting a saving of 17 cwt. of coal on every ton of iron made, or equal to 4s. 6d. In addition to this saving in coal, it will be seen from the following table that there is also a saving of 3 cwt. in ores, or equal to 2s. 5d. on every ton of pig iron produced. Nor is this all; for although those two items are the primary points of importance in the patent, it is also an ascertained fact that the heating power of the gas derived from the patent furnace represents in value—by saving a former consumption of 22 tons 8 cwt. of dross in the 12 hours at 2s. per ton—£2 4s. 10d., or equal to 3s. on the ton of iron made by this furnace. Thus upon its producing capacity for the year it gives a saving in dross alone of £1,500. This is exclusive of cost for the removal of ashes, wages, etc., which is equal to other 3d. on the ton of iron, or £125 per annum. No doubt, in a range of 8 or 12 hot blast furnaces, the quantity of gas produced would be more than sufficient for the raising of steam and heating of blast, and that possibly for a time a portion might not be utilized; but its known value is calculated to suggest other means for its application, such as calcining ironstone, etc.; but in circumstances such as exist at the Monkland Works, where there is a very large malleable work in addition to the manufacture of pig iron, the surplus gas can be applied to nearly its full extent, and thus form in the malleable department alone a very important saving in fuel. The saving proved to be effected in one furnace constructed on this principle amounts in coal to 4s. 6d., in ores to 2s. 5d., in dross to 3s. 3d., or equal to 10s. 2d. on every ton of iron this furnace makes, being equal in 1 year on a production of 10,000 tons to a sum no less than £5,083 6s. 8d. The following table gives the data carefully taken in estimating the comparative advantages of the new over the old open top furnaces:—Table showing the comparative results of the patent furnace No. 6, with an ordinary 50 ft. open top furnace,

No. 7, of the best modern construction, dating respectively from January 21st to February 10th, 1871, inclusive, being a record of 42 shifts; the materials used are the same in both cases, with the additional advantage that in No. 7 the heaters are fired with the gas obtained from the patent furnace No. 6 thereby receiving a steady temperature of blast equal to melting zinc at the external opening of the nozzle of the tuyere.

MATERIALS USED.

No. 6, or Patent.

Coal.		Ores.		Limestone.	
Tons.	Cwts.	Tons.	Cwts.	Tons.	Cwts.
1,144	45	1,127	4	409	11

Materials used per ton.

Cwt.	Cwt.	Cwt.
36.1	35.5	12.9

Production of Pig Iron.

No. 1.		No. 3.		No. 4		Total.	
Tons.	Cwts.	Tons.	Cwts.	Tons.	Cwts.	Tons.	Cwts.
489	0	189	16	35	16 =	634	12

No. 7, an Ordinary Furnace.

Coal.		Ores.		Limestone.	
Tons.	Cwts.	Tons.	Cwts.	Nons.	Cwts
1,145	6	1,071	2	375	14

Materials used per ton.

Cwt.	Cwt.	Cwt.
52	38.5	13.5

Production of Pig Iron.

No. 1.		No. 3.		No. 4.		Total.	
Tons.	Cwts.	Tons.	Cwts.	Tons.	Cwts.	Tons.	Cwts.
333	3	196	16	25	13 =	555	12

The facts brought out in the above table prove that destruction of ores takes place in the open top furnaces through the intensity of heat produced by the burning of the gas. This fact is known to exist in reverberatory furnaces, for part of the iron there passes off in a volatile condition. In the case of the blast, a similar occurrence is not to be wondered at, the temperature being sufficiently high to volatilize part of the crude materials during the process of reduction. It was at one time contended that the interior brickwork would never resist the action of the intense heat produced by the burning gas in the flues—where the temperature is fully equal to a heat competent to coke coal—and that the crossed arches in the interior of the furnace would give way, and the whole collapse. This has been proved an utter fallacy; the furnace is so constructed that the interior of the flues can be examined, as they have been from time to time, and up to the present date not the slightest change in the brick is apparent; and when we find brickwork similarly conditioned, such as in the lining of a blast furnace, from the boshes upward, lasting (as in the case of the lower part in the present furnace) for 14 years, there is not the slightest apprehenson as to the durability of the flue brickwork. Altogether, Mr. Ferrie's ingenious invention is, doubtless, destined to mark a new and important era in the manufacture of pig iron. A more prolonged series of testing will still more confirm the good results which are confidently anticipated of it. It is one of great interest to Scotch iron-masters. In Scotland alone, where the annual make of pig iron exceeds 1,000,000 tons, the saving effected in coal by his process amounts to 850,000 tons, representing in value £233,750 and in dross 400,000 tons, or equal in value to £40,000, exclusive of the estimated saving in ores also.

Railway accidents are now frequent in France. In a collision at Feugeray Lagnon between two trains, one coming from Rennes and the other from Redon, 6 people were killed and 24 injured, and at Puteaux a goods train ran into a passenger train carrying wounded Germans, 19 out of 32 carriages being broken to pieces.

The value of the telegraph wire exported from the United Kingdom in 1869, exceeded £1,000,000 in value, being the largest amount ever yet imported. The next highest amount was in 1859, when it was nearly £750,000 in value. The gross value of the telegraph wire shipped since 1855 has been nearly £5,000,000. Last year's returns are not yet published.

The new steamer "Sarpedon," commanded by Captain Charles Butler, of Belfast, has made a run from Liverpool to Hong Kong, including stoppages at Port Said, Suez, and Singapore, under 48 days.

The new Beton Coignet is to be employed in the interior of the cathedral.

CAST AND WROUGHT IRON IN COMBINATION.

From "The Engineer."

The desire to carry out in practice the principles of correct theory is one of the motives which should always actuate the engineer or architect in the preparation of his designs for any work of construction. What we wish to be understood to mean is, that on taking up the drawing of a girder, a roof, truss, or any similar professional design, the observer should be able to perceive almost at a glance that it displays an attention to scientific rules and a correct appreciation of theory on the part of the designer. But this desire, however laudable, of embodying theoretical principles in actual practice, must be kept within certain limits, and it is a knowledge and recognition of these limits that constitutes the really clever, able, professional man. There is a vast difference between drawing a girder upon paper, working out the strains upon it, and getting it built. There are two well-known instances where the endeavor to which we have alluded has signally failed. One of these occurred in the early examples of timber railway bridges in America, in the combination of the arch and the horizontal principle. It was argued, and, in a scientific point of view, correctly enough, that by making the arch take all the compressive, and the truss the tensile strains, there would result the maximum of economy in the utilization of the material. In other words, it was proposed to divide the duty of carrying the load between the arch and the truss, and so proportion their relative powers of resistance that they should each be equal to their respective tasks. With any material this precise adjustment would be impracticable, but the fallacy of the attempt was rendered the more glaring in the case of timber. Various modifications of this compound system were tried, but the passage of a heavy rolling load was fatal to them all. It is uncertain whether the arrangement would have been a complete success when the structures were loaded only statically, but the impact of a moving weight caused distortions of so serious a character, that an additional amount of bracing was necessarily introduced, which at once destroyed the economy of the design. Experience very shortly proved that the idea of apportioning the material in the two principal members of the structure—on the assumption that each would just do its work, neither more nor less—could not be entertained, and that safety required that each member should be constructed of sufficient strength to carry the whole load to which the bridge might be subjected. This conclusion being satisfactorily demonstrated, led to the abandonment of the combined system, and a return to designs of a simpler nature followed as a matter of course. A variety of trusses upon the horizontal principle succeeded to that which had proved a failure, and they in their turn are rapidly giving way to structures of iron.

Another endeavor to carry out rigidly in practice the dictates of true theory occurred shortly after the employment of cast iron for girders, beams, and for general building purposes at home. The first series of experiments, conducted with the view of ascertaining the nature and extent of the resistance of cast and wrought iron to the strains of compression and tension, established some important and, until then, unknown results. It was discovered that the former possessed remarkable strength when submitted to strains of a compressive character, while the latter was distinguished by a proportionately powerful resistance to those of a tensile nature. This result held out to experimentalists and theorists the seductive argument, that by employing the two materials in combination in beams, in which each one would be subjected solely to the strain it was best calculated to sustain, their relative advantages would be most happily secured. This was the origin of the trussed beam, which consists of an ordinary cast-iron girder supplied with a couple of wrought-iron tension rods meeting under the centre of the girder, and connected with its extremities. It was imagined that by this arrangement the perfection of economy and distribution of material would be obtained, as the top or upper flange of the beam would resist the whole of the compressive strain, and the tension rods would materially increase the strength of the bottom flange. In the

ordinary examples of cast-iron girders of the best proportions, the bottom flange has an area equal six times that of the top in order to compensate for the weakness of the metal when exposed to a tensile strain. Consequently, if wrought-iron rods could be added as auxiliaries to the girder, so as to increase the tensile resistance, a manifest economy in material would result. It remains to be seen if this addition can be made with real advantage to the strength of the beam. It must be borne in mind that the rules which govern the proportions of cast iron girders were derived from direct experiment, and, although consonant with the dictates of theory, are more or less of an empirical character. By commencing with a beam in which the top and bottom flanges were of equal sectional area, and by adding successive increments to the bottom flange, the result sought for was at last arrived at. It was not until the ratio of six or seven to one between the two flanges was reached that the upper one evinced any signs of yielding. The beams experimented upon failed, either by tearing through the bottom flange or the rib. Theory assigns that when a cast-iron girder yields to a breaking weight, the upper flange should be on the point of rupture by compression, while the lower is equally strained to the utmost by extension. Similarly in a trussed beam in which cast and wrought iron are supposed to act in concert, the former material should fracture by compression at the same time that the latter yields to the force of extension. In a word, the whole beam should "go" together, and not fail by the yielding of any particular one of its component parts. In the latter event there will clearly be an excess of strength in the part that remains intact. With respect to a trussed beam, the girder itself and the auxiliary rods should, by their united action, support the load, as they are neither of them strong enough, *per se*, to do the whole duty. If therefore, from any cause, this union of their respective powers should not be effected, a greater share of the load would fall upon one or the other than it is capable of sustaining, and the girder would fracture accordingly.

Owing to the difference in the extension and in the set of the two materials, this united action can never be satisfactorily insured, although an approximation to it may be obtained. Briefly, it is necessary to impart some degree of initial tension to the wrought iron tension rods, and the difficulty lies in proportioning the amount. If it be too low it will permit the cast iron to yield prematurely; and if, on the other hand, it be too high, the rods themselves will give way. Besides, a high initial strain upon the tension rods will produce a dangerous strain upon the cast iron; and it may be stated that it is simply impossible by any method of adjustment to cause the cast and wrought iron to be equally strained when the fracture of the girder takes place. The most advantageous ratio that can be arrived at, is that the cast iron shall yield when the strain upon the wrought equals about two-thirds of its ultimate powers of resistance—the section of the tension rods being comparatively small to that of the girder, it would appear more economical to have an excess of strength in them than in the beam—calculating upon this as the breaking weight, and bearing in mind that cast iron ought not to be loaded in practice with more than one-fourth of it, the strain upon the tension rods would equal only one-sixth of their ultimate strength, and yet wrought iron may be strained more severely with safety than cast. In the opinion of many engineers, cast-iron beams and girders ought not to be subjected in practice to a working load of more than one-sixth of the breaking weight, especially if there be any probability of their being acted upon by vibratory or concussive forces. This would reduce the working strain upon the wrought iron to one-ninth of its ultimate strength, and thus only one half of the material would be utilized. The real objection to these compound beams lies not so much in the circumstance, that it is impossible so to adjust the tension of the rods that the resistance of the cast and wrought iron shall be brought equally into play, as in the fact that they are not always to be relied on. A very little difference between the actual strain and that provided for by calculation is sufficient completely to alter their conditions of safety. It is not difficult to perceive that this element of danger exists in the girder itself by nature of its very construction. If, from any extraneous or other cause, the strain upon the tension rods

should be suddenly and seriously increased, it might induce a correspondingly heavy one upon the cast iron, and the beam might fracture at once in the abrupt manner castings always do.

Many years ago some experiments were made by Sir William Fairbairn upon the strength of trussed beams, and results obtained which were at that time regarded as rather curious. If one of Mr. Hodgkinson's girders, in its correct position, with the broad flange downwards, be trussed with a couple of tension rods, there is an increase of strength of about one-fourth. If the simple beam be placed with the broad flange uppermost, it will be reduced in strength to nearly a half of that of the simple beam in the correct position. But if we now truss the girder with its broad flange uppermost, the gain in strength is nearly three and a half times that of the simple beam in the same position, and three quarters of that of the trussed beam with the broad flange downwards. In other words, the girder which is placed in an incorrect position, and trussed with tension rods, is considerably stronger than a similarly trussed beam in the correct position. At first this appears somewhat paradoxical, but a little reflection will show that the results are quite in consonance with the rules laid down by Mr. Hodgkinson. To take the case where the beam is trussed with the broad flange, or that containing the greater section area downwards. In this instance the greater part of the material—viz., that in the bottom flange—is exposed to a tensile strain, and consequently the assistance of the wrought iron rods is not so much needed. But in the other case the larger flange is thrown into compression, thus increasing the resistance of the top part of the beam, while the deficiency in the strength of the lower flange, which would take place if the beam were untrussed, is compensated for by the high tensile strength of the wrought-iron tie-rods. Arguing solely, therefore, on the score of apparent gain in absolute strength, the method by which to obtain a cast-iron girder of maximum strength is to take one of Mr. Hodgkinson's best form of girders, turn it upside down, and truss it with a couple of stout wrought iron tension rods. That combinations of cast and wrought iron have been successfully effected in many engineering structures, every one is well aware of. There are numerous bridges still existing in which the compound system has been adopted, and there are some also which failed most completely. The principle, widely disseminated in the infancy of railway bridges, may be summed up in the words, "Make those parts of a bridge which are subjected to compressive strains, of cast iron, and those which undergo tensile ones of wrought iron." Unfortunately this maxim was carried out in many instances to the letter, regardless of all contingencies that might possibly affect the structure. It is not to be wondered at that failure was the result. Some designs are so simple and obvious in their nature that they may be safely left to the "rule of thumb," but there are others—among which may be included the system in question—which require the highest skill and care in order to insure the requisite degree of strength and security. The practical objections which obviously exist against the combination of cast and wrought iron do not prevail with the same force against combinations of cast iron and steel, a subject on which we may have more to say.

A large and distinguished party of officers, scientific men, and others, assembled at the proof butts in the Government marshes, Royal Arsenal, Woolwich, to witness a trial of the new pattern Moncrieff gun-carriage for the 7 in. breech-loading gun. Four rounds were fired with perfect success. Captain Moncrieff worked the elevator himself, and the recoil each time brought down the gun under cover to the loading position with great exactitude. The preliminary trials being now complete, the carriage will be removed to Shoeburyness for further experiments. The hydro-pneumatic principle of raising the gun will, it is thought, altogether supersede the counterpoise system, being not only much cheaper, but more simple and durable. The new gun-carriage for the 7 in. breech-loading gun is estimated to cost about £90, whereas the carriage manufactured on the original principle, for the same gun, is said to have involved an outlay of about £1000. So far, the trial of the new pattern Moncrieff gun-carriage has proved highly satisfactory.

LIGHT SEA CABLES.*

From "The Electric Telegraph and Railway Review."

The British Association, to which the civilized world looks eagerly for a record of all the advance and improvements in the numerous branches of arts and science, holds a proud position with grave responsibilities; also, as the leader of the armies of knowledge-seekers, even-handed justice is meted to the laborers in the mine of intellectual power—unworthy prejudices and the damaging influences of vested interests have no place in either her councils or rules. With these impressions of the importance and universal usefulness of the Association, I venture to ask the section to take a glance with me at the progress that has been made in ocean telegraphy, with a view to its further development. If any important branch of it has been neglected it may now be fairly discussed.

The problem of laying telegraph cables across the deep oceans of the world has been on all hands—since the Commission of Inquiry published their report in 1861—admitted to be essentially nautical in its character.

The difficulties to be overcome showed the necessity for nautical science to be consulted, not by any mere casual inquiry, but by learned and practical investigation. I fear it has not been the habit of learned societies to discuss purely nautical science, which is much to be regretted. The vast ocean field, to which the world is so much indebted, remains—in many respects—still unexplored. Gentlemen of the nautical profession do not sufficiently combine to discuss and promote thereby the honor and interests of their class as those of other professions do. Hence, no doubt, the serious mistakes that have been made in ocean telegraphy.

Von Humboldt introduced to the world some complicated theories about ocean philosophy, which has tended to perplex rather than impart practical instruction; and Captain Maury begins his very pleasing "Physical Geography of the Sea" by saying "there is a river in the ocean," but fails to show from whence it comes or to where it goes. The effect, however, was to fill the heads of gentlemen who undertook the responsibility of choosing the character of the first Atlantic Cable and laying it, with the idea that a river of unknown rapidity and dimensions must be provided against. A cable, they supposed, must be made of iron to sink rapidly in this fast-running "river," and many of their class were under the belief that even the iron cable would never reach the bottom of the Atlantic. Captain Maury, however, in later editions of his work admitted that this river was on the surface.

The laying of the 1857 cable proved there was much more in the problem of ocean telegraphy than philosophers had dreamt of. Therefore a grand scientific inquiry was instituted, a commission of eminent gentlemen was appointed, jointly by the Board of Trade and the Atlantic Telegraph Company. By this time it was clearly understood that the laying of a deep-sea telegraph cable must be intrusted to nautical skill; but, strange to say, not one member of the nautical profession had any place on the commission. It is true several nautical gentlemen were, after a fashion, examined on the subject, but they were merely witnesses, and of course had not the power to call others, or to put pertinent and practical questions, or had they any responsibility as members of the commission. This, it must be admitted, was a serious mistake, of which I at the time most strenuously complained to both the Board of Trade and Chairman of the Atlantic Company. For two years the eye of the world was on England laboring to solve the great problem of ocean telegraphy. A Blue Book, of 516 folio pages, was then presented to the world. All the practical knowledge, however imperfectly gained by the commission, unmistakably goes to prove the many advantages of a light telegraph cable for ocean purposes.

Capt. Dayman, R.N., in his practical evidence, clearly proved this to every candid inquirer—(see the Blue Book of 1861, page 181.) I regret there is not time here to make elaborate quotations. The selection and loss of the 1857 Atlantic cable, and all the subsequent consequences, arose from a vague idea that there

*From a paper read before the British Association by Capt. W. Rowett.

were dangerous currents in the Atlantic, but by what law of nature as to their course, their strength, or their depth, they were regulated, nothing whatever seems to have been known; nor were any experiments instituted to prove any kind of theory, though this could have been easily done in the English Channel. With no unkindly feeling do we now refer to it, only as a beacon pointing out danger, and as a help to a more perfect solution of the problem. If, as it was supposed, there were abrading movements of the sea at extreme depths, a heavy iron cable such as would lie undisturbed was truly indispensable. If, on the other hand, there was no abrading motion at such depths—that it was entirely a mistake—then a cable of iron, or one loaded with iron, was not at all necessary. On the contrary, the cable that was made of the lightest material, provided it was the strongest fibre, and it did not absolutely float, would in every respect be the best; such cable would lie light as a feather on the bed of the ocean, and in time of need, be easy to lift from its resting place. Its tensile strength would be used to overcome displacement only, and not to lift from the bottom a heavy load, as the iron cables were, and which had so severely tried the skill of everybody to lay it safely, and when laid, to bring it again to the surface.

We need not here dilate upon the strength and spacific gravity of the various kinds of hemp and other fibrous material, for they can be mixed as may be found desirable. But for the purpose of our present argument, we class them as one, in contradistinction to metallic productions. A properly made hempen telegraph cable could be recovered from any depth in the Atlantic by the most simple process, because of its light specific gravity coupled with great tensile strength. Its capability to lift greater lengths of submerged cable in proportion to its specific gravity is clear, I presume, to every one's mind. A familiar illustration, however, will make it unmistakable to the general reader, however unnecessary for professional gentlemen. Let us suppose a telegraph cable made of iron wire the size of the Atlantic Cable of 1857, to weigh in water 1 lb. to the fathom, there would be no difficulty in laying it in a depth of 40 fathoms, because its dead weight is of course only 40 lbs. When the ship is still, and, under all circumstances, it is easily controlled even by hand. But mark the contrast: when the same cable is being laid in 2,500 fathoms, then the dead weight, when the ship is still, is no longer 40 lbs., but is in proportion to the depth 2,500 lbs., which is about equal to the weight of the lower anchor of a 1,000 tons ship. The cable being only the size of a man's finger, I need not say the weight is far too great to be safely controlled under the various circumstances that might arise on being laid.

Nearly 7 years passed before capital could be obtained for making the second Atlantic Cable, the specific weight of which was then happily reduced by putting a large mixture of hemp with the wire. It is not my intention to refer especially to the exact dimensions of that cable, but to proceed with the illustration which shows the true principle of ocean cable philosophy. By the mixture of hemp with wire, the cable being the same size as the one we have taken as data, we have reduced its weight when submerged from 1 lb. to 12 oz. to the fathom. Thus, in a depth of 2,500 fathoms, the dead weight is reduced to 1,875 lbs. This is a decided step in the right direction; the specific gravity of the cable being so much reduced, it is easier controlled when being laid, still its weight is far too great and altogether unnecessary.

It contains also other elements of insuperable danger to the perfection of a deep-sea telegraph cable—to which I may presently refer. It is admitted now by all concerned in ocean telegraphy that light cables are the *sine quâ non* of all ocean cables. But where lies the limit to which the lightness may be carried? Are the cables that have been successfully laid so light specifically as true science would justify? I answer emphatically, no! If, for example, a cable the size of which we have been speaking—having the same displacement to overcome—occupying the same space on ship board, be made to take another step in the direction of light specific gravity, not by reducing it from 12 to 6 but to 1 oz. to the fathom, thus the dead weight submerged in a depth of 2,500 fathoms would be reduced from 1,875 lbs. to 156 lbs. Light as 156 lbs. may be considered, it will sink at the speed of over 2 miles an hour, and when made of

double hard strands of pure and simple hemp, whatever may be the kind, it can be made as solid and unstretchable in water as an iron cable of the same size. 14 miles of such cable would weigh submerged 780 lbs., which is not one-third the weight it would bear, and on the authority of the Commission to which I have referred, an iron cable will break with the weight of 3 miles of its own length.

Some years ago, I was honored by Government with a request to furnish an estimate for making and laying a deep-sea telegraph cable, and its accompaniments, which were of various kinds. One provision was, that in case the cable broke in the operation of laying it, a number of grapnels and some 12,000 fathoms of large rope were to be provided, with which to recover the cable if it were lost. In replying to this request, I called attention to Captain Dayman's well-known soundings in the deepest parts of the Atlantic, which he invariably took with a hemp line; how he obtained samples of the soft ooze bed of the ocean; how he failed at any time to discover any under-currents, for, as he states, the slack sounding line went directly down and coiled itself upon the lead. In proof of this, the coils getting entangled with the sinker, on one occasion 200 fathoms of the line were hauled up in one lump with the sinker. I explained to them that, as Captain Dayman proved, there was a perfectly quiet soft bed of ooze on which the cable would lie undisturbed; that there were no currents to interfere with its passage there; and that his sounding line was a fit illustration of the character of the cable that would take the best possible care of the electric conductor—the hemp line had only to be enlarged to the dimensions required by the properly chosen core in the centre, it would run out from the ship as gently and be under as perfect control as a common log line, however tempestuous the weather. If the use of a heavy cable was so unsafe as they seemed to imply, they admitted a light cable could take care of it. I would, therefore, strongly recommend them to adopt the most common-sense view of the case, and put the electric wire into the hemp cable, which would save also the cumbrous and complicated machinery used for paying out the heavy cable. This communication had the effect of changing the views of the Government, and they abandoned their project without adopting my recommendation, for they were powerless against parties otherwise interested.

We have still to speak of the advantages of the simple hempen telegraph cable in various points of view. The economy of its construction and its portability must be evident to every one at all conversant with such matters. It must be clear also that if a cable can be laid across oceans at vastly reduced cost and risk—and this is as certain as there is truth in science—the effect must be universally felt when messages which now cost 30s. will be reduced to 5s., and so telegraphy will be brought within the reach of the millions of every country. The pofits to be derived from this expansion of telegraphy we may confidently believe will be as large from the low as from the high rates of charge, to say nothing of the civilizing and commercial advantages gained to the world, besides adding largely to the industry of the laboring classes. Other advantages of importance are gained by the use of hempen cables. It is clear of the destructive iron which is always a danger to the electric condition of the cable as well as a dangerous weight, and every way much more expensive when iron forms any part af the cable. On the other hand, the hemp rope is not only a natural bed in which the electric core can lie, but the hemp holds a preserving solution, which for all practical purposes makes it indestructible—keeping the strength of the cable intact for any period of time. At the same time the pure and simple hemp cable becomes so hard when in contact with water, that it will bear its entire tensile strength without elongating over 3 per cent.

From the Darien Canal surveying expedition very important intelligence has been received. Captain Selfridge, the commander of the expedition, writes from Paye, that he has discovered a route for the canal, the summit of which is but 300 ft. above the ocean, and that the route begins near the mouth of the Atrato river. If Captain Selfridge is not deceived as to the feasibility of this route, his discovery will have a most important influence upon the world's commerce, and will solve the Darien problem.

THE INFLUENCE OF INTENSE COLD ON STEEL AND IRON.

From "Nature."

There has recently been a most interesting discussion at the Literary and Philosophical Society, Manchester, on the above subject, the result of which seems to be that we must at once give up the idea that such accidents as the one, for instance, near Hatfield, are due to anything beyond the control of the railway companies concerned.

The paper which gave rise to the discussion was by Mr. Brockbank, who detailed many experiments, and ended by stating his opinion that iron does become much weaker, both in its cast and wrought state, under the influence of low temperature; but Mr. Brockbank's paper was immediately followed by others by Sir W. Fairbairn, Dr. Joule, and Mr. Spence, which at once put an entirely new complexion on the matter.

As Dr. Joule's results are the most to the point, we may take them first. He says:

"As is usual in a severe frost, we have recently heard of many severe accidents consequent upon the fracture of the tires of the wheels of railway carriages. The common-sense explanation of these accidents is, that the ground being harder than usual, the metal with which it is brought into contact is more severely tried than in ordinary circumstances. In order apparently to excuse certain railway companies, a pretence has been set up that iron and steel become brittle at a low temperature. This pretence, although put forth in defiance, not only of all we know of the properties of materials, but also of the experience of every-day life, has yet obtained the credence of so many people that I thought it would be useful to make the following simple experiments:

"1. A freeezing mixture of salt and snow was placed on a table. Wires of steel and of iron were stretched so that a part of them was in contact with the freezing mixture, and another part out of it. In every case I tried, the wire broke outside of the mixture, showing that it was weaker at 50 deg. F. than at about 12 deg. F.

"2. I took 12 darning needles of good quality, 3 in. long, $\frac{1}{24}$ in. thick. The ends of these were placed against steel props, $2\frac{1}{8}$ in. asunder. In making an experiment, a wire was fastened to the middle of a needle, the other end being attached to a spring weighing machine. This was then pulled until the needle gave way. Six of the needles, taken at random, were tried at a temperature of 55 deg. F., and the remaining six in a freezing mixture which brought down their temperature to 12 deg. F. The results were as follows:

Warm Needles.	Cold Needles.
64 oz. broke	55 oz. broke
65 " "	64 " "
55 " "	72 " "
62 " "	60 " bent
44 " "	68 " broke
60 " bent	40 " "
Average $58\frac{1}{3}$	Average $59\frac{5}{6}$

I did not notice any perceptible difference in the perfection of elasticity in the two sets of needles. The result, as far as it goes, is in favor of the cold metal.

"3. The above are doubtless decisive of the question at issue. But as it might be alleged that the violence to which a railway wheel is subjected is more akin to a blow than a steady pull; and as, moreover, the pretended brittleness is attributed more to cast iron than any other description of the metal, I have made yet another kind of experiment. I got a quantity of cast-iron garden nails, $1\frac{1}{4}$ in. long and $\frac{1}{8}$ in. thick in the middle. These I weighed, and selected such as were nearly of the same weight. I then arranged matters so that by removing a prop I could cause the blunt edge of a steel chisel, weighted to 4 lbs. 2 oz., to fall from a given height upon the middle of the nail as it was supported from each end, $1\frac{1}{16}$ in. asunder. In order to secure the absolute fairness of the trials, the nails were taken at random, and an experiment with a cold nail was always alternated with one at the ordinary temperature. The nails to be cooled were placed in a mixture of salt and snow, from which they were removed and struck with the hammer in less than 5 seconds."

The collective results of the experiments, the details of which need not be given, was that 21 cold nails broke and 20 warm ones. Dr. Joule adds:

"The experiments of Lavoisier and La-

place, of Smeaton, of Dulong and Petit, and of Troughton, conspire in giving a less expansion by heat to steel than iron, especially if the former is in an untempered state. Such specimens of steel wire and of watch spring as I possess expand less than iron. But this, as Sir W. Fairbairn observed to me, would in certain limits have the effect of strengthening rather than of weakening an iron wheel with a tire of steel.

"The general conclusion is this: Frost does *not* make either iron (cast or wrought) or steel brittle, and that accidents arise from the neglect of the companies to submit wheels, axles, and all other parts of their rolling stock to a practical and sufficient test before using them."

Mr. Spence, in his experiments decided on having some lengths of cast iron made of a uniform thickness of $\frac{1}{2}$ in. square, from the same metal and the same mould. He writes:

"Two of the four castings I got seemed to be good ones, and I got the surface taken off, and made them as regular a thickness as was practicable.

"I then fixed two knife-edged wedges upon the surface of a plank, at exactly 9 inches distance from each other, with an opening in the plank in the intervening space, the bar being laid across the wedges; a knife-edged hook was hung in the middle of the suspended piece of the bar; to the hook was hung a large scale on which to place weights.

"The bar was tried first at a temperature of 60 deg. F.; to find the breaking weight I placed 56 lbs. weights one after another on the scale, and when the ninth was put on the bar snapped. This was the only unsatisfactory experiment, as 14 or 28 lbs. might have done it, but I include it among the others. I now adopted another precaution, by placing the one end of the plank on a fixed point and the other end on to a screw-jack, by raising which I could, without any vibration, bring the weight to bear upon the bar. By this means, small weights up to 7 lbs. could be put on while hanging; but when these had to be taken off and a large weight put on, the scale was lowered to the rest, and again raised after the change was made. I may here state that a curious circumstance occurred twice, which seems to indicate that mere raising of the weight, without the slightest apparent vibration, was equal in effect to an additional weight. $3\frac{3}{4}$ cwts. were on the scale, a 14 lbs. weight was added, then 7 lbs., then 4 lbs., 2 lbs., 1 lb., and 1 lb., making 4 cwts. and 1 lb. This was allowed to act for from 1 to 2 minutes, and then lowered to take off the small weights, and replaced by a 56 lbs., intending to add small weights when suspended, raised so imperceptibly by the screw, that the only way of ascertaining that it was suspended, was by looking under the scale to see that it was clear of the rest. As soon as it was half an inch clear, it snapped, thus breaking at once with 1 lb. less than it resisted for nearly 2 minutes.

"Six experiments were carefully conducted at 60 deg. F., the parts of the bars being selected so as to give to each set of experiments similar portions of both bars; the results are marked on the pieces. My assistant now prepared a refrigerating mixture which stood at zero, and the bars were immersed for some time in this, and we prepared for the breaking trials to be made as quickly as could be, consistently with accuracy, and to secure the low temperature, each bar, on being placed in the machine, had its surface at top covered with the freezing mixture. The bars at zero broke with more regularity than at 60 deg., but instead of the results confirming the general impression as to cold rendering iron more brittle, they are calculated to substantiate an exactly opposite idea, namely, that reduction of temperature, *cæteris paribus*, increases the strength of cast iron. The only doubtful experiment of the whole twelve is the first, and as it stands much the highest, the probability is that it should be lower; yet, even taking it as it stands, the average of the six experiments at 60 F. gives 4 cwt. 4 lbs. as the breaking weight of the bar at that temperature, while the average of the six experiments at zero gives 4 cwt. 20 lbs. as the breaking weight of the bar at zero, being an increase of strength from the reduction of temperature equal to 3.5 per cent."

Sir W. Fairbairn's evidence is of great importance, for he not only gives facts showing that frost does not affect the tires, but he states the real cause of such accidents as are generally attributed to the frost. He states:

"It has been asserted in evidence given at the coroner's inquest on the Hatfield

accident, that the breaking of the steel tire was occasioned by the intensity of the frost, which is supposed to render the metal brittle, and of which this particular tire was composed. This is the opinion of most persons, but judging from my own experience, such is not the fact, and provided we are to depend on actual experiment, it would appear that temperature has little or nothing to do with it. Some years since, I endeavored to settle this question by a long and careful series of experiments on wrought iron, from which it was proved that the resistance to a tensile chain was as great at the temperature of zero as it was at 60 deg. or upwards, until it attained a scarcely visible red heat. To show that this was the case, and taking, for example, the experiments at 60 deg., it will be found that the mean breaking weight, in tons, per square inch, was in the ratio of 19.930 to 21.879, or as 1 : 1.098 in favor of the specimens broken at the temperature of zero. The generally received opinion is, however, against these facts, and it is roundly asserted that the strength of iron and steel is greatly reduced in strength at a temperature below freezing. The contrary was proved to be the case in wrought-iron plates, and assuming that steel follows the same law, it appears evident that we must look for some other cause than change of temperature for the late fracture of the tire on the wheel of the break-van of the Great Northern Railway. * * * * The immense number of purposes to which both iron and steel are applied, and the changes of temperature to which they are exposed, renders the inquiry not only interesting in a scientific point of view, but absolutely necessary to a knowledge of their security under the various influences of those changes ; and when it is known that most of our metal constructions are exposed to a range of temperatures varying from the extreme cold of winter to the intense heat of summer, it is assuredly desirable to ascertain the effects produced by those causes on material from which we derive so many benefits, and on the security of which the safety of the public frequently depends. It was for these reasons that the experiments in question were undertaken, and the summary of results are sufficiently conclusive to show that changes of temperature are not always the cause of failure, as that which occurred near Hatfield on the Great Northern Railway. That such is the fact, I may adduce several accidents of broken tires, all of which occurred during the spring and summer months when the temperature was high. One of them occurred on the Lancashire and Yorkshire Railway in the summer of last year, when the temperature was 50 to 60 deg. above freezing. I could enumerate others in which the winter frosts had nothing to do with the fractures which ensued."

After refeiring to some other experiments, Sir W. Fairbairn proceeded :

"The danger arising from broken tires does not, according to my opinion, arise so much from changes of temperature as from the practice of heating them to a dull red heat and shrinking them on to the rim of the wheels. This, I believe, is the general practice, and the unequal, and in some cases, the severe strains to which they are subject, has a direct tendency to break the tires. To show how easily this may be effected, let us suppose that a tire 2 ft. 6 in. or 3 ft. diameter, is shrunk on to a wheel $\frac{1}{4}$ in. larger than the tire, it then follows that the tire in cooling must be elongated to that extent, with a strain equivalent to the force of the shrinkage, and calculated to produce that amount of molecular disturbance. It may be more or it may be less, but supposing the strain to be one-half or three-fourths of that which would break the tire, it then follows that the constant action of its irregular motion on the rails must ultimately lead to fracture. I am not surprised that this should be the case, as most if not the whole of railway tires, excepting those on engines and tenders, are not turned, but selected by hand, heated and shrunk upon the wheels with every degree of tension, as suits the convenience of the workman. So long as this process is pursued the public will be exposed to the risk of broken tires. What is required in this description of manufacture is, that the rim of the wheel and the inside of the tire should be turned to a standard gauge, accurately calculated to give the required amount of tightness with a larger margin of strength, and this done, we should attain greatly increased security to the public, and a great saving in wear and tear—to say nothing of the large sums expended by companies in the shape of compensation for injuries and loss of life."

Here, then, is another potential triumph for more scientific accuracy and more hope for travellers.

* * * * * *

Upon the above discussion, "Engineering" comments as follows :

As to the effect of cold on the tensile strength of steel and iron, we fully agree with the results of experiments, such as those made by M. Styffe and others, which show that the power of these materials to sustain dead weight is rather increased than diminished by cold ; but it is difficult to establish any definite relation between tensile strength and resistance to concussion, and more particularly to the effect of numerous small vibrations.

There can be little doubt, moreover, that iron and steel are sensibly affected by changes of temperature, the more extreme these changes and the more suddenly they are brought about the greater being their influence on the strength of the materials exposed to them. The quality of iron, too, varies greatly, and as the variations in quality greatly modify the power of the material to resist particular kinds of strain, it is the duty of railway engineers to study both the mechanical properties and chemical composition of the iron employed by them, and to select those kinds best suited to the particular work they have to perform. Thus it has been shown that phosphorus, when present in iron, diminishes the resistance of that material to impact at low temperatures, although at the same temperatures it by no means exercises a similar influence on the resistance to steadily applied tensile strain ; and thus we are led to the conclusion that such iron is unfitted for employment in situations in which it will be subjected to the combined influence of severe cold and concussion, although it may safely be employed in cases where, although exposed to cold, it is subjected to steady strains only. It should be remembered, however, that all railway plant is subjected to concusions of a more or less violent kind, while the greater the speed at which the traffic is carried on, and the less perfect the condition of the permanent way and rolling stock, the more severe such concussions are. Thus we find that in Russia the experience on the railways has proved decisively that the sharper concussions produced by an increase of speed result in an increased number of breakages.

As to the difference between wrought-iron and steel in resisting the influence of a cold climate, we think that there can be no doubt that a mild steel, containing no more than from $\frac{1}{3}$ to $\frac{1}{2}$ per cent. of carbon, decidedly deserves the preference. In fact, the results obtained by the extensive use of steel tires, axles, and rails, in cold climates, such as Canada, Russia, and Sweden, prove practically what might have been anticipated on theoretical grounds, namely, the advantages to be derived from the use of mild steel. We hope before long to have an opportunity of again speaking on this subject, but meanwhile we would direct attention to those countries which are less favored in respect to climate than our own for experience as to the influence of cold on iron and steel. For we must remember that while we in England have occasionally a winter like the present and that of 1862, with the thermometer down to 10 deg. Fahr., railway men in Russia, Sweden, and Canada, have very often, if not indeed every year, to deal with such temperatures as—30 deg. Fahr., and have yet to carry on their traffic with safety. We may, therefore, well take lessons from them, even while we congratulate ourselves on being placed under more favorable conditions.

In conclusion, we desire to say a few words as to methods of testing iron and steel. We much wish that as a general rule materials for railway plant were subjected to tests corresponding tolerably closely to the actual work which such materials have to perform, and, as nearly as possible, under similar circumstances. Iron and steel used in the construction of railway plant should be tested for hardness, homogeneity, and resistance to impact, and if the tensile strength be ascertained, the recorded results should also show the limit of elasticity and the elongation before fracture. For bridge-work, the materials should be tested for tensile strength, elongation, and resistance to impact, simultaneously, while for roofs or buildings subjected to statical strains, the tensile strength and the stiffness are perhaps the qualifications which it is most desirable to ascertain with accuracy. In addition to the mechanical tests, the chemical composition of the materials should be the object of careful investigation in order to ascertain the amounts of carbon, silicon, phosphorus, sulphur, etc., present;

and, lastly, the mechanical tests should be applied at temperatures similar to those to which the materials would be exposed in actual use. Were these precautions more generally observed, the right material would be used in the right place, and numerous failures of a disastrous and frequently costly kind would be avoided.

ZINC AND ITS MANUFACTURE.

From "The Mining Journal."

Apropos of the recent publication of certain statistics of the zinc manufacture, by M. Ed. Fuchs, and of the annual report (April, 1870) of the largest zinc-producing company in the world, we purpose to review in brief the history and position of the zinc trade. Although known as a substance whose mixture with copper produced brass, and though worked for this object from the 15th century, the ores of zinc failed to furnish the metal as a branch of industry until the 19th century. In England, so early as the 16th century, the metal was isolated by Paracelsus, but no further advance seems to have been made towards its economic application, until in 1805, after an extensive series of experiments to reduce the carbonate to the metallic state, a Belgian chemist, L'Abbe Dony, succeeded in obtaining the metal by sublimation. The rude apparatus in which Dony first accomplished the condensation of zinc has, with slight modifications, been largely employed ever since, under the name of the Belgian process. This apparatus was no other than a flower-pot, fixed in the side of his furnace, and having a hole pierced through, the better to observe the progress of the operation. In this recess the zinc deposited in little drops. The metallurgy of zinc was known. The flower-pot has been replaced by retorts, provided with movable horn-like prolongations, in which the metal collects; the number and size of the retorts have been gradually increased, but the process remains to this day substantially as Dony left it.

Simultaneously with Dony's invention at Liége, a similar process was discovered in Silesia. The sinkings for coal at Tarnowitz had disclosed vast beds of calamine, which, though inferior in point of purity to the Belgian ores, were of sufficient importance to create a new and flourishing industry. Here the reduction of the ore, previously pulverized and mixed with ground coal, was accomplished in a muffle, terminating in its upper extremity in a tube, which passed through an aperture in the side of the furnace, and, bending downwards siphon-wise, allowed the condensed metal to flow out. The siphon form has, however, been abandoned in favor of a series of double recesses, in which the zinc collects, and is removed by a descending pipe into cast-iron cups. A third method was practised for sometime in England, known as distillation *per descensum*, in which the ore was reduced in retorts or crucibles, arranged on the shelf of a furnace of the ordinary glass-house form. Through the bottom of each crucible a pipe descended to the cool cavity underneath. This opening in the bottom of the crucible was closed at the commencement of each operation by a wooden plug, which, becoming converted into charcoal by the heat, allowed the zinc vapor to percolate through its pores, and run down the tube into the receiving vessel. This system, though it is said to yield good results, is wasteful in fuel, and is now generally abandoned in favor of one of the processes before mentioned, or some modification of them.

The first zinc works was established at Liége, by Dony, in 1807. It was supplied with ore from the calamine beds of Moresnet, of which he had obtained the lease. But Dony paid the price of most inventors — he enriched the world and impoverished himself. Finding the demand for the new metal increase so slowly, and his resources gradually diminishing, he was at length obliged to sell the lease of his rich zinc mines, after having worked them for eight years. These deposits of zinciferous carbonate have since acquired a world-wide notoriety in the hands of the Vieille Montagne Company.

The mining of the ores of zinc is by no means of so recent date as its metal-

lurgy. So early as 1425, the annals of the Duchy of Limbourg mention the calamine explorations of Altenburg ; and for a long time blende and carbonate of zinc have been mined, as secondary products, in Rammelsberg and other parts of the Hartz Mountains. The chief ores for industrial purposes are blende, a protosulphuret, and calamine, a carbonate of zinc, having very frequently an admixture of silicate. Though theoretically richer in metal than the carbonate, blende is more difficult in its treatment, and yields a less percentage to the manufacturer. The carbonate occurs both in veins and beds, in the Devonian measures of Ardennes, the Hartz Mountains, and the Erzgebirge, and among the limestones of Derbyshire and Cumberland, and in the transitional rocks of Hungary and Silesia. It sometimes forms the lining on the cheeks of lead veins, and sometimes is associated with the galena, in which case it is never very dependable, its continuance being often abruptly supplanted by blende, galena, or pyrites. This is especially the case in the zinc mines of Spain, and in the newly-opened workings in Sardinia. Blende occurs chiefly as an alternative in lead mines, and sometimes in copper and other metalliferous veins, but it is occasionally found in masses, like the Cornish "floors," or the German "stockwerk," as in the rich mines of Iglesias, in Sardinia, and of Stollberget and Ammeberg, in Sweden. About half of the zinc ores of Europe is supplied by Prussia. In Silesia there are 30 mines in operation, partly worked by shafts and partly by levels driven into the hills. They employ 15,000 workmen, and yield annually 221,000 tons of calamine. In Westphalia, 70,000 tons are supplied from 75 works. The Rhine ores consist of blende, largely mixed with lead and iron. In some parts the iron reaches 18 per cent. of the calcined ore, but no effort has yet been made towards its utilization. Here 6,000 men are employed. Belgium, the oldest zinc-producing district, supplies 57,000 tons, Poland 12,000 tons, and Spain 50,000 tons. These ores are chiefly the carbonate, containing portions of blende and galena. France contributes 3,000 tons, and Ammeberg, Sweden, 12,000 tons. The sulphuret from these Swedish mines is very pure, and admits of tolerably easy reduction. From Iglesias 20,000 tons come. This district in Sardinia has but recently become a producer of calamine. In 1866 the total quantity raised was 13,000 tons ; increased in 1869 to the amount given above. Immense stores of calamine enrich Sardinia, and the supply seems to be only limited by the difficulties of transport, which, it is said, will prevent the annual yield from exceeding 40,000 tons. These Sardinian deposits are regarded as the only carbonates at all comparable, in point of purity, to the far-famed calamine beds of Moresnet and Tarnowitz. America produces about 12,000 tons ; but the disorganization of the civil war interrupted the annual reports after 1863, until recently. In Italy and other countries, including England and Algeria, where, at the present moment, a Belgian company is preparing to open out a zinc mine, 12,000 tons are raised.

In the metallurgy of zinc, the first point to be accomplished is its slow and uniform roasting. This is effected at present in a furnace, whose sole is divided into two or three compartments, of varying heats, and the ore is drawn from the first to the next, at intervals of about eight hours, in such manner that the mineral is first gently heated, and gradually increased to the utmost power of the furnace. A self-acting machine has been invented by M. Gerstenhöfer, to avoid the immense hand labor involved in this operation. This apparatus is used in England and Belgium to some extent, but does not seem to fulfil all the desirable conditions, and the ore calcined is neither so uniformly nor so thoroughly roasted as by the hand method. From the calcination the ore is carefully ground, and mixed with coal dust. Coke dust is used in Silesia, to avoid the stoppage of the pipe that delivers the zinc from the muffle, by the adhesion of the tarry matters of raw coal. Here very little labor is required from the workmen ; the zinc continues to condense and flow down the siphon to the end of the operation. In the Belgian process, however, when the ore has been placed in the retorts, and has begun to sublime, the horn-like prolongations are taken off every two hours, and carefully emptied into the receiver. The fact that this method requires a lower temperature than the Silesian process, has been utilized in arranging some Belgian retorts

above the ordinary Silesian furnace. This method has been established at the zinc works of Valentin Cocq, with a considerable economy of fuel. The cost of the Belgian and Silesian processes is about equal, the first having an advantage in fuel, and the second in hand labor, and in the longer endurance of the furnace. The points to which attention is directed to reduce the cost of zinc production are, to augment the yield by increasing the size and number of the retorts, and to reduce the amount of fuel consumed. In the Belgian furnace it is customary to arrange 70 retorts, and from 30 to 40 in the Silesian, the daily yield amounting respectively to 11 cwt. and 20 cwt. The fuel required in the Silesian furnace is $2\frac{1}{2}$ tons of coal per ton of ore. Three-fourths of the metal contained in the ore is by these means extracted. With the object of still further reducing the expenditure of fuel, which in Prussia and Belgium is more costly than with us, various forms of grate have been tried for the reducing furnaces, with but partial success. An English patent taken out some two or three years ago, by Messrs. Tildesley & Bird, seems to us most likely to answer the purpose. Furnace grates, similar to Siemens', are used with moderate success in France and Silesia.

The metallurgy of zinc, like its mining, is confined to a few centres. In England, the principal works are Messrs. Vivian's, at Swansea, and these depend partly on foreign supplies of ore. The entire produce of Europe is 120,000 tons ; of this Prussia contributes 80,000. The largest of the Prussian works is the Silesian Society of Mines and Foundries, which keeps in activity no less than 150 furnaces, and turns out annually 8,000 tons of raw zinc, and the same quantity of sheets. The cost of the reducing operations at these works is 11s. 10d. per cwt. of zinc produced ; and the selling price at the market town, some miles distant, has been for the average of the last few years 22s. 4d. per cwt. The extra cost for rolling is 1s. 3d. per cwt. of sheets. This price is slightly augmented in the case of the thinner varieties. The largest zinc works in the world is La Vieille Montagne, near Liége. Last year this company raised 68,379 tons of ore, and in their own two collieries 89,452 tons of coal, while the total manufacture of zinc attained the amount of 44,441 tons, of which 35,213 consisted of sheets, 5,965 of zinc-white, and the rest of various castings—ingots, wire, nails, ornaments, etc. The entire sales of this company last year, according to the official report of April 30, 1870, amounted to the sum of £1,000,000, being 30 per cent. of the entire produce of Europe, and resulting in a gross profit of £212,557, which allowed a dividend to be declared of 25 per cent. on the capital. At these works sheet-zinc is rolled to any thickness. The plates are rolled at a temperature of about 212 deg., which heat is generally developed by the pressure of the process. The specific gravity is thereby increased from 6.8 to 7.2.

Two-thirds of the total quantity of zinc produced is manufactured into sheets, the remaining one-third is employed for brass-making, for wire, for zinc-white, as a substitute for lead in paints, and for castings, which last, by the way, are made in moulds of iron instead of sand, thereby attaining a cleanness and finish before unknown, besides considerably reducing the expense of manufacture. That the consumption of zinc is far from having attained its normal development may be seen from the fact that while France consumes 35,000 tons annually, and Great Britain and her colonies 30,000, and Belgium 6,500, Germany uses but 22,000, Italy, Russia, Spain, and other countries together only 10,000 tons. The two chief requirements for zinc sheets are roofing and sheathing the bottoms of ships, the usual thicknesses for roofing purposes being from .028 in. to. 044 in., while for ships' bottoms they vary from .038 in. to .048 in. Mr. Daft, an English engineer, has recently proposed an ingenious application of zinc sheeting to iron ships, whose chief advantage seems to be the avoidance of vegetable and animal growths on the bottoms of vessels by means of the galvanic current set up between the two metals when in the presence of salt water.

The inventor of the Bavarian "mitrailleuse" received $4,000 for the invention, and he gets an additional sum of $120 as royalty on every mitrailleuse which leaves the Government manufactory.

THE COMPOUND STEAM ENGINE.

At a recent meeting of the New York Society of Practical Engineering, Mr. Charles E. Emery gave the following brief statement of his views concerning the advantages of the compound steam engine as compared with the ordinary double-acting engine.

1. It furnishes a better working engine, mechanically, for utilizing the benefit of the expansion of high pressure steam.

This point will be very generally conceded. The expansion of steam is necessary to secure economy; but if the application of the principle be carried to the extent desired, the great changes of pressure in the cylinder cause severe strains on the main connection, and although the latter be made unusually strong, it is frequently found expedient to reduce the pressure, and necessarily the measure of expansion, and so increase the consumption of fuel, in order to reduce the losses caused by frequent repairs, but more particularly by the delays they occasion. The compound engine, in any form, equalizes the strains and distributes the load.

2. Independently of mechanical considerations, it is more economical to use steam expansively in a compound engine than in any form of the ordinary engine.

This point must be accepted as a fact by any one who will examine the evidence available, but the abstract explanation of the result is impossible by any of the laws heretofore laid down in respect to the steam engine.

It should be borne in mind that, contrary to the opinions of many, there is no gain in power by the addition of the small high-pressure cylinder of the compound engine, for the effective pressure upon its piston is only the difference between that of the entering steam and that admitted to the second cylinder. There is, in fact, a little power *lost* in transferring the steam from one cylinder to the other. It is not strange, then, that nearly all American engines condemn the compound engine and declare, in spite of all failures, that the same result can be produced in a single engine if it be made of sufficient strength to withstand the unequal steam. These engineers simply judge from the information they have had the opportunity of acquiring. They have been taught that the capacity of the cylinder is the measure of the steam used, and reason that if the compound engine gives no more power with the same steam, it is a useless contrivance. No other conclusion could be based on such an assumption. The error in the reasoning lies in the fact that the volume of the cylinder is not an accurate measure of the quantity of steam used by the engine. This fact has been proved by experiment, both at home and abroad, but, strange to say, has never attracted much attention. People will assume that steam *can* be measured by the cylinder fully as accurately as peas in a bushel; but the fact is, that the metal walls of a steam cylinder are at every stroke so cooled by the performance of work, and by the low temperature during the exhaust, that the live steam, upon entering, has two offices to perform, viz.: 1st, to reheat the surfaces, and 2d, to fill the cylinder and maintain the desired pressure. In many cases it may require as much steam to do the first as the last; and as the steam for the first purpose is condensed, that for the second will only fill the space; and, in fact, two volumes of steam may enter a vessel capable of holding but one of a liquid or non-condensable gas.

During the Government expansion experiments, and others of a private character, I had ample opportunity to ascertain the accuracy of the above views, and found that the benefits to be derived from expansion were, in the manner stated, greatly reduced, though not entirely overcome, as had in some cases been claimed.

I believe these losses could be prevented, and, with means furnished by capitalists, have tried over 250 experiments to ascertain the value of the various devices for accomplishing this end. The nature of the loss was proved in the following manner: "I constructed two cylinders of like dimensions, one of glass, the other of iron, in such a manner that either could be attached to a valve which regularly admitted steam from a boiler to the cylinder and permitted its exhaust into a condensing coil lying in a tub of water." The capacity of the two cylinders was

made the same, as was shown by transferring water from one to the other. When put in turn in condition of a steam-engine cylinder, the iron cylinder used (averaging the experiments) fully twice as much steam as the glass one, shown by the fact that twice the quantity of water came through the condensing coil for the same number of movements of the valve. Steam of the same pressure was used in both cylinders, and the experiments were many times repeated, with substantially the same results. This settles the question. The glass cylinder saved half the steam. The cylinder of a perfect engine should, then, be made of glass or other non-conducting material, which may be explained in the following manner: Tyndall has found that aqueous vapor is one of the most powerful radiators and absorbents of radient heat known. Steam, when slightly chilled by the performance of work, is in respect to heat in the same condition as the aqueous vapor of the atmosphere; therefore, if steam enters a cylinder at, say, a temperature of 280 deg., and heats the metal surfaces to that point, when such steam is exhausted and falls in pressure so that the temperature is only, say, 130 deg., the surfaces rapidly radiate heat, which is absorbed by the steam and carried to waste; and the next steam that enters has to re-heat the surfaces, and an additional quantity is required to fill the cylinder and do the work. A non-conducting cylinder does not become cooled, and only the exact quantity enters which is required to fill it.

I experimented considerably to make an engine with a cylinder of non-conducting material, and only desisted, temporarily, when it occurred to me, and I proved by experiment, that nearly the same result could be obtained by the use of a modification of the compound engine which involved no difficult mechanical details.

The transfer of heat from the metal walls of the cylinder to the exhausting steam takes place in two ways, viz.: by direct contact and by radiation. The bulk of the steam can only be acted upon by radiation, which therefore causes the material part of the loss.

It has been proved by experiment that the quantity of heat transferred from a radiating to an absorbing body varies as the square of the difference of temperature of the metal surfaces; so, taking the previous case, viz.: that the temperature of the metal surfaces of a steam cylinder is 280 deg., and that of the exhaust steam 130 deg., the difference in temperature is 150 deg.; and, if we use the steam in two cylinders instead of one, we may reduce the temperature in each to, say, $\frac{1}{2}$ that amount, and the condensation will be 1^2 to 2^2, or $\frac{1}{4}$ as much in the two cylinders as in the single one, or not less than $\frac{1}{3}$ as much, if an allowance be made for the increased surface in the two.

This explanation shows that if the condensation in the single cylinder be $\frac{1}{2}$ the whole amount, that $\frac{2}{3}$ of this, or $(\frac{2}{3} \times \frac{1}{2})$ *one-third* of the whole may be saved by the compound engine, which calculation agrees with the facts, but varies, of course, with the changes in the conditions.

The explanation once obtained, it enables one who has studied the subject to proportion the compound engine so as to obtain the maximum efficiency. I have known many of them that were so constructed that they gave but little better results than a single engine. In addition to the above, it is well to state that during the experiments several improvements applicable to the compound engine were worked out, which, in connection with the principle, using a steam pressure of only 40 lbs., reduced the cost of power in the experimental engine from 39.2 lbs. of feed water per horse-power per hour to 23.6 lbs. This proportion of saving would, in a larger engine, reduce the cost to as nearly that promised in my theory as the most sanguine could expect, for large engines are positively known to be more economical than small ones, which may be explained by the fact that the ratio of internal surface to capacity decreases with the size of the cylinder.

Further details would make this communication too lengthy. I should be happy to furnish you with a more elaborate discussion of the subject if desired. The practical evidences of the advantages of the compound engine are overpowering, as nearly all the large ocean steamships recently constructed abroad have such engines. One of these vessels, 400 ft. long, according to the statement of a representative, crossed the Atlantic inside of 12 days, with a consumption of only 40 tons of coal per day.

THE BALANCE DOCK BASIN AT POLA.*

The harbor of Pola, naturally favorable for the purposes of a naval station, was selected by a committee of Austrian engineers and officers, as the most suitable that could be chosen for the extensive arsenal and dockyards, which it would be necessary to construct when the port of Venice was abandoned. It was situated directly south of Trieste, on the western coast of the peninsula of Istria, south-west of Fiume, and about 60 miles distant from both those ports. Venice, on the other side of the Adriatic Sea, was 80 miles distant in a north-westerly direction.

It was at first intended that excavated docks should be formed, but in consequence of the volcanic and treacherous nature of the ground, this idea was found to be impossible of execution. A Floating Dock, Basin, and Railway system were therefore decided upon, the dock adopted being that known as Gilbert's Balance Floating Dock. The basin and railways were in general principles the same as those constructed at the United States Navy Yards at Portsmouth, New Hampshire, and at Pensacola, Florida. These were the first dock basins with railways that had been constructed, and were commenced in the year 1849.

The function of a basin for a floating dock was to supply a place in which the dock itself might be grounded, either with a vessel upon it to undergo extensive and prolonged repairs, or to enable the vessel to be hauled out of the floating dock upon the railways, which latter operation was only required in cases where vessels were moved from the dock to land above the sea level, or the reverse. A basin to fulfil these requirements must be so constructed as to permit the dock to be floated into it, and the entrance closed by means of gates or caissons.

The general dimensions of the basin at Pola, determined by the magnitude of the floating dock, were as follows :

	Ft.	In.
Width inside the enclosing walls.....	211	6
Length.....	311	6
Depth from the top of the walls to the stringers in the floor of the dock...	17	1¼
Depth from the level of ordinary high water to the top of the stringers....	13	0
Depth from the level of ordinary low water to the top of the stringers...	11	0

The maximum difference in the hydrostatic head, inside and outside the basin, existing during the progress of the construction of the basin, was 20 ft.

Detailed surveys and sections of the site were taken, so as to determine the precise contour of the rock, and of the mud overlying it, which varied in thickness from 2 ft. to 12 ft. As the rock was unfitted for holding, or even for receiving sheet piles, except when they happened to strike a fissure, it was decided not to use the ordinary clay-puddle cofferdam.

The material selected for the walls of the basin was Santorin béton, composed of Santorin earth—a volcanic product from the Greek island of Santorino—and lime paste, in the proportion of 7 to 2, forming the hydraulic mortar ; to this was added 7 parts of broken stone, the mixture being made into a conical heap and tempered by exposure in the open air for from one day to three days, when it was ready for use. Of this béton extensive wharves and moles had already been constructed at Trieste, Fiume, and Pola ; and, as it had been found durable and efficient, was moderate in cost, and obtainable in any quantity, it was considered that no better material could be determined upon for the walls of the Pola basin. It might be mentioned that the largest blocks previously made were those at the mole of Fiume, which were 25 ft. in vertical depth, 22 ft. wide at the top, with a batter of 1 in 4 or 1 in 6, and 50 ft. long.

It was believed that, by adopting proper precautions, the mud which covered the rock bottom would form a suitable foundation for the walls of the basin, provided that a water-tight joint could be made at the bottom of the wall, for there could be no leakage or percolation through the béton, so long as it remained uncracked by unequal strains or settlements. It was, however, assumed that such cracks would occur, and that it would be necessary to provide for such a contingency.

A wall of a plain rectangular section

* From a paper read before the Institution of Civil Engineers, London, by HAMILTON E. TOWLE, C. E., of New York.

was decided upon, the thickness of which was determined with reference to the fact that the foundation consisted of greasy mud, lying at angles varying from 2 deg. to 10 deg., which would render a slip possible. Joints were made across the wall, at intervals of from 40 ft. to 90 ft., in order to form weak places, which, being selected with reference to the nature of the bottom, would in all probability determine the location of any cracks that might occur.

It was ascertained by calculations, based upon the data afforded from a knowledge of the contour of the rock bed and the mud bottom, that no crack could exceed 6 in. as a maximum, and the ends of the blocks marked the localities where the settlements would probably take place. To check the passage of the water through the wall at these points, as well as to prevent the blocks from moving laterally upon one another, a rectangular post, 18 in. by 24 in., was inserted vertically in each of the joints, reaching from the upper surface of the block, through the mud, to the rock bottom below. These posts projected 12 in. into each block of béton. Subsequent experience proved that this device was thoroughly efficient, the largest crack, which had a maximum width of $5\frac{1}{2}$ in., not admitting any water. The thickness of the walls varied from 15 ft. to 20 ft. and 26 ft. The floating dock entrance was placed on the north side, and was adapted for an iron caisson to close it. This entrance was 120 ft. wide in the clear, but the caisson measured 128 ft. along the top line. The pump well was situated in the south-west corner of the basin. Great care was taken to make the stage piles stand vertically, as they were to remain permanently in the walls. The vertical diagonal bracing between the piles was removed as the béton was filled in. The enclosing sheet piles were carefully squared, so as to obtain perfectly true faces, for the purpose of obtaining tight joints, and to give the béton walls, of which the sheet piles formed the moulds, a fair surface.

To facilitate the operation of driving the piles in line a machine was specially devised by the Author, and termed by him a "spider." This consisted of two horizontal timbers, 35 ft. long, placed parallel to each other and kept 12 in. apart (12 in. being the thickness of the sheet piling) by distance pieces. From the forward end of these timbers, two other timbers, also 12 in. apart, sloped backwards and upwards, while at about 8 ft. from the same end an oak block was passed between and bolted to the horizontal timbers, and this also sloped backwards and upwards, until it intersected the other two raking pieces before described and was bolted to them. This frame was hung by two vertical rods of wood to the staging above, and was free to swing to and fro; ropes and tackle were attached at the rear end, by which the frame could be moved in any desired direction, while, by a strong hawser fixed to the forward end, the jaws, formed by the horizontal timbers and the raking pieces, were made to embrace closely a short length of sheet piling already driven, the machine being hauled up so taut by the hawser that the raking oak block pressed against the face of the pile. The distance at which the "spider" was suspended from the staging was such, that the end of a pile about to be driven was engaged in the guide formed by it before its vertical position was affected by its tendency to float. When it was in operation the hawser at the forward end was hauled tight, and the end of the pile, pressing against the guide, extended the rope sufficiently to force the "spider" back, and permit the pile to pass and be driven in its exact position. It was found by experience, that with this machine at least double the amount of work could be done, and all the piles were kept exactly in their proper position.

When the sides of the enclosure for one block had been completed, and the cross dams and the vertical timber joint before described had been put in, the section was bolted together above the level of the béton work, and the operation of filling in was commenced, the average time required for this being two weeks. After the walls had been finished, the tie bolts clamping the sheet piles against the sides of the blocks were gradually loosened, to enable the former to settle freely and to compress the mud from below. At the same time the interior rubble wall was built upon the top of the béton, to a level above high water, to form a dam. The sheet piles were subsequently cut off by a circular saw, and the exposed ends were

covered by an external sloping embankment, or apron, of broken stone and sand. The principal internal filling of the basin having been completed as the previous work progressed, as well as a temporary clay-puddled coffer-dam closing the opening for the iron caisson, the pumping machinery was erected, and on the 2d of February, 1859, the operation of emptying the basin was commenced.

As was anticipated, the butt joints between the béton blocks were found to open, more or less, according to the character of the mud on which they stood. and the contour of the rock bed, but in no case did the timber joints fail. After the maximum settlement had developed itself, the cracks were carefully cleaned out, and filled with masonry to the depth of 1 ft. from the face of the wall, and tubes or pipes were inserted in the wall, for conveying away any slight leakage that might escape, without washing away the fresh mortar. Where a crack or joint appeared open on the external side of the béton walls, a pad, secured to a plank or timber, was firmly braced against it, until it was tight enough to prevent the escape of fine mortar or cement. The openings or cracks were then filled with thin grout, injected through a tube, under a head of about 10 ft. above the wall.

As soon as the basin was emptied, the work of laying the floor was commenced. This consisted of 30 rows of foundation piles, capped with timber 1 ft. sq., bedded in 6 in. of béton. Upon the top of the piles was fastened close planking 6 in. thick, and over this was laid the masonry, forming and completing 9 lines of stringers, varying from 8 ft. to 12 ft. in width, to receive the bottom of the dock when grounded.

The space of several hundred feet between the southern end of the basin and the island (Scoglio d'Olivie) was filled in, and two sets of railways, resting on pile foundations, were laid.

The caisson for closing the opening to the basin was built by the Messrs. Rennie, of London, and was found to answer its purpose completely.

ERECTING BRIDGES WITHOUT SCAFFOLDING.

From "The Engineer."

The Jumnah, the Saone, the Sutlejh, and many other large rivers of India have been already spanned by railway bridges, but as yet the Ganges has never been polluted by the shadow of a locomotive thrown upon its sacred waters. That event is, however, close at hand. The Oude and Rohilcum Railway crosses that river at Cawnpore, and the structure that is to convey the trains across is in process of rapid construction at the premises of Messrs. Campbell, Johnstone & Co., at Silvertown. It is intended to adopt, not a new principle, but a novel method of erecting this bridge ; and it was to witness the application of this method that a large party of engineers and other gentlemen interested in such matters proceeded on Friday week to the works of the firm in question. We will describe, first, the bridge, and then the manner in which it is proposed to dispense with the adventitious assistance in scaffolding and staging. The bridge may be stated to be a tubular lattice, if that term may be used with propriety. It is intended to carry a double roadway, one over the other, consisting of a single line of rails and an ordinary thoroughfare. The latter is carried in the lower portion of the structure, and the former overhead. As the weight of the traffic on the roadway may be regarded as insignificant compared with that on the rails, the girders may be considered, as far as the rolling load is concerned, as loaded on the upper booms. This might be surmised from the large quantity of bracing disposed horizontally between them. Looking at the girder in elevation, it is divided into so many panels by vertical compression members, which have the appearance of being carried across the space between each pair of parallel girders, both above and below. This arises from the fact that the lower and upper cross girders are placed at the junction of the verticals with the booms. In the transverse section the cross girders and verticals compose a system of rectangular frames which unite the separate girders into one structure, and constitute the skeleton or frame-

work of the whole bridge. The girders are evidently designed in accordance with an axiom that is an especial favorite with some engineers: "Always make your struts as short as possible." We shall not now enter upon any discussion of the real economy of this principle of construction, but merely state that vertical struts and diagonal ties do not necessarily make an economical bridge. When the rolling load is considerable, compared with the dead weight of the structure, the bars of the web, near the centre particularly, have to support strains of both tension and compression, and counterbracing of some sort must be introduced. At the centre of the girders under notice intersecting diagonals are introduced for this purpose, but theoretically the effect of these, as there are vertical bars as well, is only to cause a confusion in the direction of the strains, and practically a superfluous amount of material. But as this reduplication of the bars of the web occurs at the central bay only of the girder, it is of no importance, and in all other respects, omitting the consideration of the principle, the web is a good specimen of lattice work. It is entirely free from the common error, perpetually displayed, of placing the bars too closely together, and, at the same time, the distance between them is so adjusted as to allow of the conditions, assuming a uniform distribution of load on the flanges, being practically fulfilled. As the strains upon the flanges can only be induced through the medium of the connecting bracing or web, the distance apart of their relative connections must determine whether the former are strained progressively from the ends towards the centre, or whether "per saltum." It is not necessary to remark that in the latter case, the girder would have to be constructed in an especial manner that would be usually troublesome, complicated, and expensive.

The minimum number of spans that must of necessity be made continuous, either temporarily or permanently, to enable a bridge to be erected without scaffolding, is two. When the girders covering the double span are in position, there will be three points of support, and when they are in motion there will never be less than two. Before describing the actual manner in which the continuous girders traverse successively the various points of support, until communication is established across an inaccessible distance, a word must be said about the special apparatus employed in the experiment. Briefly, it consists of a set of hydraulic presses, supporting at their upper extremity a number of wheels. The bottom flanges of the girders are furnished with a tee-shaped longitudinal piece of wrought-iron. The rib of this rests upon the periphery of the wheels. The latter are caused to revolve by being connected with toothed wheels, which are worked by an endless screw. As they revolve, the friction upon the rail is sufficient to produce the advance of the girders. Five men are required at each side of the pier or support, so that, in all, ten men are sufficient to move the pair of continuous girders. The whole manipulation is exceedingly simple and efficacious. Let us now investigate the mode of erecting the bridge on its permanent site, bearing in mind that there are 23 spans, each 100 ft. in length, and a couple of land spans of smaller dimensions. It is only the actual framework or skeleton of the bridge that will be launched from pier to pier in this manner; the two platforms, that of the roadway underneath and that of the railway above, will be laid afterwards. In the first place, the two pairs of continuous girders must be riveted up with their connecting bracing complete on the solid ground, in the rear of the abutment which is to constitute the starting point. If we call these girders Nos. 1 and 2 we have them supported at three points, with the free extremity of No. 2, reckoning from the land, resting upon the abutment, and ready to be launched into space. In this position there are three sets of presses and rollers required. One set is on the abutment, another is on the point where the two separate pairs of girders are continuously united, and the third is on the bridge, to be used as will be shown presently. The free end of girder No. 1 is merely supported on packing, as the least movement will cause it to swing clear of its bearings. The object is now to launch the girder over span No. 1. The ten men go to work on the abutment at the screws, and girder No. 2 commences to advance into space at the rate of 40 ft. per hour, so that, allowing for contingencies, it will

reach the first pier in three hours' time. Directly the intervening distance is spanned the set of presses that has been carried over the space with the bridge is placed under the girders on pier No. 1, while at the same time the set that was originally under the centre of the continuous span, but is now under the free end of girder No. 1, is removed and placed on the bridge, to serve in its turn for pier No. 2. A repetition of this operation carries the continuous girders right across the river, until they occupy the twenty-second and twenty-third spaces respectively. The set of presses and rollers are conveyed back again, and the same process recommenced with another pair of continuous girders. Bearing in mind that the common difference is equal to two spans, it is readily calculated that at this rate it would take six weeks or two months to get all the girders in their permanent positions, not including the time necessary for fixing them.

The experiment having been very successfully carried out, which included the moving of the girders forward some 20 ft. or 30 ft., the party, numbering about five-and-thirty, adjourned to luncheon, provided with much taste and hospitality by Messrs. Campbell & Johnstone, in the spacious upper story of one of their workshops. Sir John Rennie was in the chair, with Mr. Heppel at his right hand, and after a few toasts the visitors left for London by an early train, after expressing the satisfaction and pleasure the trip had afforded them. It is, of course, one thing to carry out an experiment in a workshop, where there is an entire absence of wind, and other disturbing causes, and another to perform the same feat upon the site of the bridge ; but from what we have witnessed we have little doubt respecting the actual success. At least we hope there will be no hitch, for should one of the girders happen to topple into the river, the Hindoos will be certain to ascribe it to the anger of their deity, and a just punishment for invading the sanctity of the holy stream. Regarding the effect upon the girders themselves of this method of erection, we shall have something to say on another occasion.

AMBIGUITY IN TESTS OF IRON-WORK.

From "The Mechanics' Magazine.

The usual assumption, so frequently put forward, that because any piece of mechanism, or any structure of iron or other material, has once withstood a given pressure or strain, it will in future not give way under one of a less amount, must not be received unreservedly. Its subsequent safety and immunity from danger from strains of a lesser severity than those which constituted its proof test, will depend, not so much upon the actual magnitude of the force applied, as upon the proportion the strain bears to the limits of elasticity of the material. On the one hand, it would obviously be exceedingly remiss on the part of those responsible for the strength of any structure to permit it to be employed in situations where its failure would be attended with fatal results, without subjecting it to some kind of test or proof, in order to obtain a practical and reliable knowledge of its resisting capabilities. Again, on the other hand, it would be erring in the other extreme to cause the proof applied to be so excessively severe in character as to jeopardize the future security of the structure. Much difference of opinion prevails among engineers on this point. Some consider that the ratio of the testing to the breaking strain of the material should be very high, while others advocate the employment of more moderate proof strains. In our opinion the latter is the more judicious of the two methods. A moderate proof load is quite sufficient to demonstrate whether the example in question is able of performing the ordinary duty that will devolve upon it, while a very severe one cannot do more, and at the same time may permanently damage the structure. The over-testing of any piece of mechanism or example of construction may be not inaptly compared to the over-training of a young athlete. When the powers are over-taxed, they are inadequate to perform their work when the time arrives. It should be borne in mind that the mere capability of resisting, without indicating

palpable symptoms of weakness, any given strain, is not by any means an absolutely reliable criterion of the strength of any piece of construction. If the example be of a complicated nature, there is the character of the workmanship to be taken into account as well. It might be executed in such a manner that, while capable of withstanding a heavy strain upon it for a short time, it would infallibly give way under the continued application of one of a considerably less amount. Independently of the reasons that we shall refer to which indicate that excessive proof tests should not be used, there is the undeniable fact that iron structures do subsequently yield under a much less strain than that which they bore apparently with ease at the time of testing. What is more common when one of these catastrophes occurs than the exclamation "Oh! it bore three times that load when it was tested?"

It was but the other day that a crane broke while used for lowering some workmen, and the accident terminated fatally. It is stated that the load which occasioned the fracture was 12 cwt., and that the crane had previously been tested with a proof load of a couple of tons. Here we have an instance of a specimen of iron construction giving way under a load that is three and a half times less than that which it withstood with impunity as a test. This is one of the most recent examples that has come under our notice, but it would be easy to give a long list of similar ones that have occurred at intervals ever since the introduction of cast and wrought iron as materials suitable for engineering and architectural construction. The fact of the subsequent yielding of iron-work to strains inferior to those with which it was taxed at its proof trial is not confined solely to small specimens such as cranes, but is equally true for larger and more pretentious structures. Bridges that have successfully passed the ordeal prescribed by the regulations of the Board of Trade have subsequently been found to fail under loads of a less amount than those which constituted their preliminary trial. A railway bridge that is passed by the Inspecting Officer of the Board of Trade as perfectly safe for traffic may, in the course of a few years, become so insecure as to require extensive repairs before it can be again used for locomotive purposes. This result may proceed from one of many causes. It may be due to an originally bad design, defective workmanship, inferior quality of material, or to a combination of these. A well-known instance in point is the Crumlin Viaduct. This is a bridge belonging to the Warren type of girder, in which the connections between the web and flanges are made by pins instead of rivets. It may be observed that this principle of attaching the web and flanges is adopted in the Charing Cross Railway Bridge, but, nevertheless, it will never make so complete or so rigid a connection as when the pins are replaced by rivets. This was found to be the case with the Crumlin Viaduct. The pins got loose, as all pins must inevitably do in the course of time, and it was necessary to make good the attachment of the web and flanges with gusset pieces and rivets. This was effected, and the structure placed once more in a condition fit for traffic.

Returning to the subject of the test load, it may be asked what should be the maximum strain that ought to be imposed upon a structure of wrought iron, in order that while, on the one hand, its capabilities for resisting subsequent strain should not be impaired, on the other, those capabilities should be put to a reasonable proof. It must be borne in mind that action and reaction are equal and opposite, or in other words, Hook's law, *sic tensio, ut vis*, holds good for iron up to a certain point. It is impossible to arrive at the exact strain that, preliminarily imposed upon any particular structure or piece of iron-work, will impair its future powers of resistance. Evidently, in this case, a great deal must depend upon the character of the example experimented upon, and whether its design be simple or complicated. If it be of the latter description, and composed of a great number of individual component parts, which are attached to one another by bolts or rivets, the first effect of the test load will be to adjust the relations of these parts, or to bring them all to their bearings. A portion of the load may therefore be fairly considered to be absorbed in accomplishing this mutual arrangement, and it is not until this result is effected that the structure becomes really sensible of the strain applied to it. Those who have had ex-

perience in the testing of iron girders, especially those intended for locomotive traffic, are well aware of this fact. The action of the test load is rendered manifest by the deflection of the girder, and it is a well-known and remarkable circumstance that the deflection of a girder, when first tested, is always greater than that arising from a repetition of the same load. Clearly, this is due to the adjustment of the parts, as already mentioned. When they have once been brought to their bearings, there is no further deflection to be obtained from their action. In mathematical language, the quantity representing their deflection has been eliminated from the calculation. There is, therefore, a difference between the deflection first observed in a girder submitted to a certain proof load, and that which attends the girder under a repetition of the same load. This difference may be great, or it may be small, and its proportion will depend upon the superiority or inferiority of the workmanship. The better the workmanship the closer and more firmly will all the parts be united together, and enabled to act as one solid mass, rather than as a combination of numerous component parts. To a certain extent, therefore, the difference between the first and any subsequent deflection of a girder under a given load may be regarded as a criterion of the character of the workmanship. Viewed in this light, there is an ambiguity in the test, as it is not solely a measure of the absolute strength of a girder, but also of the nature of the workmanship.

The fact of the difference in the first and future deflections of a girder under the same proof load not being a complete indication solely of the character of the workmanship, is due to another circumstance which we shall now refer to. If the adjustment of the relative parts were the result only of practical imperfections in the methods of their attachment to one another, there would be no necessity for going any further. But there is another cause which must be taken into account also, when the example is of a complicated nature similar to that under consideration. In a girder composed of an open web and upper and lower flanges, one half of the diagonals, under the ordinary conditions of a superimposed weight, will be in tension, and the other half in compression. But these strains of tension and compression will not be produced, at least not to any very appreciable extent, until the load is placed upon it. It is evident that the bars will receive their initial straining from the test load, and will afterwards not to be so susceptible of the effect of any force applied. It might be perhaps remarked here that, as the deflection of a bar or of a girder is approximately a measure of its strength, a bar or girder that deflects less on the second or other succeeding application of a given weight ought to be stronger than it was when first subjected to its influence.

At first sight this may appear a little paradoxical, but it is nevertheless the fact, at any rate so far as the deflection may be considered a criterion of strength. So well is this principle known that it is a common, but at the same time a very reprehensible practice to place heavy weights upon a girder or iron structure that is liable to a Government inspection and testing. By thus subjecting the structure to a preliminary proof, it exhibits consequently less deflection on subsequent testing. As deflection offers the readiest and in many instances the only means of arriving at an estimate of the resisting capabilities of a structure, it is no wonder that it sometimes passes for being stronger than it really is.

The limits of elasticity of wrought iron have been stated by different writers at various figures, but this discrepancy may possibly arise from the fact that different qualities of iron were employed in the experiments. Mr. Barlow, a well-known authority on all such matters, found it to be about 10 tons, while other equally able and reliable experimentalists have determined it to be as high as 12 tons and more. There is no doubt that iron of a superior quality might be fairly considered to possess a range of elasticity reaching to 12 tons, but when it is borne in mind that the majority of iron-work is rarely constructed of any but ordinarily good iron, it will be far safer to take the lower amount for the standard of calculation. This should be more especially kept in view when the iron-work is designed to fulfil a duty that will subject it to the action of forces of a concussive or impactive character. The effects of overstraining, particularly if it be accom-

panied by shocks and sudden violent wrenchings, is to render iron that is otherwise of a soft ductile nature, exceedingly hard and brittle. In fact, there is very little doubt that incessant repetitions of impactive forces tend in the course of time to completely alter the molecular constitution of the material, and, in a word, to convert wrought iron into cast. In instances where wrought-iron chains have been fractured after withstanding for some years violent jerks and shocks, it has been very difficult to discover any evidence that the material was originally wrought iron, the section of fracture resembling that of cast iron, scarcely a trace of any fibrous consistency remaining. Whatever, therefore, may be the character of the material, or the design of the structure it is clearly unadvisable to subject it to any proof strain exceeding the limits of elasticity.

THE PROPERTIES OF ELASTIC TIRES.

By LIEUT. CROMPTON, R.E.

From "The Engineer."

The question of elastic tires as applied to traction engines, heavy guns, in fact, to any wheeled carriages intended to cross soft or rough ground, is one that is exciting considerable interest amongst the mechanical engineers of the day, and the object of this paper is to draw attention to the various advantages as well as disadvantages of the system, and to bring to the notice of the engineering public several properties which appear to have escaped general attention.

Throughout this paper I use the word elastic tires, meaning thereby tires possessing elastic properties in the highest degree at present obtainable. I have not hitherto met with any arrangement of metallic spring tire that can be at all called elastic in the same sense that rubber is elastic, *i. e.*, capable of restoring by its instantaneous expansion in rear of the wheel nearly the whole of the power expended in compressing it in front of the wheel. The reader must therefore understand that whenever the words elastic tires are used, solid ring tires of the best and softest rubber obtainable in the market are meant. The properties of elastic tires are—(1) Their effect in reducing rolling resistances over rough or soft surfaces; (2) in producing increased bite; (3) their use as friction brakes; (4) use as springs; (5) in reducing wear and tear of engine; (6) in reducing wear and tear of highway.

To compare the rolling resistance of a train and wagons mounted on rigid wheels with one mounted on wheels with elastic tires, I will put six cases likely to be met with in ordinary work across country, and note in a tabular form the rolling resistance in each case in pounds per ton.

Case 1.—Over very good pavement. In all these cases, for the purpose of argument, the question of slip, etc., being laid aside, the way level and straight :—

Rigid tires, supposed to be rigid steel rollers, 5 ft. diameter, 12 in. wide on face of tire.	Elastic tired wheels, rubber tires 4½ in. thick, 5 ft. diameter over all, 12in. wide on face of tire.
Total resistance... 60	Total resistance... 70

Case 2—Over good macadamized road in fair order, all conditions as above :—

Rigid.	Elastic.
Total resistance... 70	Total resistance... 70

Case 3.—Over ordinary macadamized road of an average quality :—

Rigid.	Elastic.
Total resistance...120	Total resistance... 80

Case 4.—Over road newly coated with gravel :—

Rigid.	Elastic.
Total resistance...300	Total resistance...100

Case 5.—Over newly-broken stone, other conditions as above :—

Rigid.	Elastic.
Total resistance...440	Total resistance...110

Case 6.—Over soft grass land :—

Rigid.	Elastic.
Total resistance...300	Total resistance... 80

I do not pretend to extreme accuracy in these figures; but they are sufficiently near the mark for all purposes of comparison, and will be substantiated by any one who has ever used rigid and elastic tired traction engines working side by side, as was the case with the writer for many months together. But any one who

has ever been in the omnibus fitted with Thompson's rubber ring tires, that ran for some time between Leith and Edinburgh, cannot have failed to notice that, running over pavement, macadamized broken stone, or soft muddy road, it was all one to the engine that drew the omnibus, and hardly any variation in her pace, which was that of a fast horse omnibus, could be observed.

The apparent cause of the superiority of the elastic over the rigid tires, in cases 3, 4, 5 and 6 is this, that the principal cause of rolling resistance, on a road more or less perfect, is the inequality or roughness of the surface. The wheel is always either ascending or descending minute prominences on a good road, larger ones on a bad one, or if the load on the wheel be heavy enough, in crushing them to a nearly level surface, and so much resistance is due to this that it amounts in an extreme case, viz., that of a road newly covered with broken stone, to one-fifth of the weight carried on the wheel. The elastic tire, on the other hand, allows these prominences to sink into its under surface, preserving all the while a tolerable level on its upper surface. Let the reader imagine to himself a level macadamized road, half of which has been carefully rolled by a steam roller to a nearly perfect surface, the other half being covered with loose road metal. If the rigid wheels I have taken as an example be drawn over these two surfaces in turn, the resistance will be found to be. 65 lbs. per ton over the rolled, and 440 lbs. over the loose surface; let both surfaces be completely covered with a carpet of rubber, $4\frac{1}{2}$ in. thick, and the same wheels be then drawn over them, the resistance over the rubber which covers the rolled surface will be 70 lbs., and over that which covers the loose part will be only 110 lbs. We do not exactly know to what the increased 5 lbs. in the former case is due, but no doubt some part of it is expended in overcoming the friction of the rubber when it is expanding laterally over the smooth surfaces of the tread of the wheel and of the road. In the latter case considerable additional power is expended in forcing the rubber into intimate contact with the very uneven surface of the road; still, however, the gross resistance met with is only one-fourth of that over the bare loose surface.

Let the reader now imagine a strip of this carpet, of the exact width of the tread of the wheel (which must be so proportioned as not to sink into the rubber to an injurious extent) to be cut out, and the ends brought together, and joined so as to form a solid ring. We have now the elastic tire, the properties of which I am describing, and which behaves in exactly the same manner in affecting rolling resistances as the complete carpet of rubber does.

The question of the superior bite of the elastic over the rigid tire reduces itself to a question of extent of surfaces in contact. In the case of the rigid tire this surface approaches *nil*, or a theoretical line, according as the wheel and road are more or less rigid and unyielding. In the case of the elastic tire it varies as the thickness and softness of the rubber. To take an example:—A 6-ft. diameter rigid tired wheel on a macadamized road with a good foundation, width of tire 18 in., has a surface of contact of, say, at the utmost, 18 in. $\times$ 2 in. = 36 sq. in. An elastic tired wheel, tire $4\frac{1}{2}$ in. thick, also 6 ft. diameter over all, same width, and loaded to same weight, say three tons, will have a surface of contact with a similar road of 18 in. $\times$ by 18 in. = 324 sq. in. if gray rubber be used, or 18 in. $\times$ 24 in. = 432 in. if red rubber be used. In the first case we have 9 times, and in the second 12 times the surface. I may here notice that this enormously extended surface will at once explain the marvellous properties of elastic tires when going over soft ground.

Some of my readers will at once exclaim, "But one of the first axioms in mechanical engineering is that the friction of the rubbing surfaces does not vary as their area, but as the weight which forces them together." To this I reply that this axiom only applies to bearings or other rubbing surfaces of machinery, which are made as smooth as possible, and carefully prevented from coming into direct contact, and thus interlocking by the interposition of some lubricant. But let these two mechanically smooth surfaces be encouraged to interlock, by taking away the lubricant, and artificially roughening them with small teeth or other asperities, the axiom above quoted will no longer hold good; and if several sets of bearings or rubbing surfaces thus roughened be taken, all carrying the same load but varying in area, the friction will be found to increase

with the area; and the case of a wheel rolling on a road is precisely similar—one at least of the surfaces is soft enough to allow the asperities of the other to sink into and interlock with it. The rigid tire sinks into the road, and the elastic tire allows the road to sink into it. In either case we have interlocking, but of course in the latter case we have extended area—hence the increased bite. The bite obtainable for tractive power from these increased surfaces amounts in extreme cases to 65 per cent. of the load carried on the wheel. Some experiments were carefully carried out in France with traction engines, under the superintendence of Messrs. H. Tresca and General Moran. From their report, dated February, 1868, I learn that the utmost coefficient of adhesion of a rigid wheel upon a dug macadamized road in a good state of repair is 30 per cent. of the load carried on the wheel.

The following table will give at a glance the advantages possessed by the elastic tire:—

Case.	Percentage of adhesion	Description of engine, wheel, road, etc.	Remarks.
A	17	Rigid wheel on a dry paved street.	Experiment made on of 1–16.
B	20	Elastic tired wheel on hard frozen ground coated with ice; tire consisting of segments of very hard rubber held in their places by shoes.	Do. do., 1–13.
C	27	Ordinary rigid wheels on good macadamized road in dry weather.	Do. do., 1–12.
D	29	Elastic tired wheels over hard frozen ground coated with ice, being solid ring tires with shoes on.	Do. do., 1–20.
E	30	Tresca and Moran's limit of adhesion for rigid wheels on very good macadamized road.	From many experiments on levels and on an incline, 1–30.
F	26	Elastic tired wheels over clear hard ice, being solid ring tires without any shoes.	On an incline, 1–11.
G	55	Adhesion of elastic solid ring tires with shoes over them on fair macadamized road.	On various inclines, computed from many experiments.
H	65	Limit of adhesion of solid elastic ring tire with shoes over them on good macadamized road.	On an incline, 1–20.

It will be noticed that I have given no cases of rigid tires being tried on unfavorable roads, such as in cases B, D, and F, or on greasy paved streets, greasy macadamized roads, grass land, clay, sand, etc., the reason being that rigid wheels possess practically no adhesion at all on such surfaces; and if a traction engine be taken out under such circumstances she will be unable to move herself, let alone her load, and has to be helped home by other power.

In case F, the data were obtained from calculations based upon the work which has been done during the late hard weather by a traction engine belonging to Mr. White, of Kettock Mills, near Aberdeen. By the constant flow of water over the steepest part of the road, a mass of solid ice was formed on an incline of 1 in 11, and on such a surface the engine found no difficulty in taking herself and her load, total 16 tons, at a considerable speed, with a consumption of fuel of 1.75 lb. per ton per mile (gross load, including weight of engine).

Any one who has ever driven a train of wagons, drawn by a traction engine along a highway, must have noticed that it is absolutely necessary to make all the couplings between the engine and wagons perfectly rigid, so as to allow no longitudinal play, not even so much as in an express train on a railway. Consequently, if the engine be geared directly to her driving wheels, without the intervention of a friction brake, it will require an unnecessary powerful engine to start a heavy train, and all traction engine makers have found this friction brake necessary; but it is extremely difficult to adjust to the load, and requires constant attention. If, however, the elastic tire consists of a solid rubber ring, slipped over the driving wheels (which have their peripheries turned up perfectly smooth) and kept in its place by flanges, it forms the most perfect friction brake we know of.

When the engine is starting a heavy train, the driving wheels make some portion of a revolution within the tires, varying with the load, and the train gathers way, and moves off as smoothly as it is possible to conceive, even if the regulator handle be opened full at once. There is no wear and tear of the internal surfaces of the tire, in consequence of this use as a brake. The sand or mud, or whatever foreign substance gets between the periphery and the tire, beds itself in the rubber, and wears down the periphery of the wheel, but leaves the tire practically uninjured. So much so is this the case, that an engine in India, after running some 2,000 miles over the dustiest roads perhaps in the world, exhibited literally no wear whatever on the inner surface of her tires. I lay stress on this fact because it has been stated that great wear and tear took place on the inner surfaces, because it was out of sight it had not been noticed by the general public.

The quality of the rubber used is of great importance in its effect on the adhesion of the tires and of their durability. Red rubber, although it is most expensive, and, being softest, gives the greatest percentage of adhesion, is very uncertain in its composition, and, consequently, is not to be trusted to for tires intended for extreme climates. Gray rubber, which is much cheaper, is harder, but can be thoroughly depended on. Some other kinds of rubber, still harder, have been tried, but there appears to be no gain in their wear as regards durability, and considerable loss as regards adhesion and use as springs.

Traction engine makers for years past have been endeavoring to perfect some arrangement of springs by which the injurious vibration caused by the jolting over a rough road might be lessened, and as yet no springs have been fitted that will work, for this reason—that if the driving axle does not maintain its parallelism with the crank shaft, but constantly varies its position, the effect will be that each end of it will at one time overrun, at another time lag behind its own end of the crank shaft, the torsional strains on which will be so great as ultimately to cause its failure, particularly if the engine be worked at any speed. The elastic tire, however, forms a very perfect spring, and, as it is placed in the most favorable position in which a spring can act, viz., between the wheel and the ground, instead of between the load and the wheel, it not only preserves the load—that is, the engine itself—from injurious jolting and vibration, but reduces the wear and tear on the wheel itself and its axle to a minimum. This is not the case with the ordinary spring, as the wheel and axle, being between it and the road, have full liberty to use their whole momentum to pound themselves and the road to pieces. Traction engines, fitted with elastic tires, have consequently been able to attain high speeds of 10 and 12 miles an hour without injurious results to the machinery. In fact, in the case of the Indian engine above quoted, the vibration felt by any one standing on the foot-plate when she is running at 8 miles an hour, over a macadamized road in fair order, is infinitely less than that of an express engine running at the moderate speed of 30 miles an hour over good track.

The wear and tear of highway when traction engines or other wheeled carriages having rubber tires are run over it is absolutely *nil.* When guards or shoes are used over the rubber it becomes appreciable, but is still so small that no other wheeled carriage can compare favorably with them, even if ever so lightly loaded. I will quote a case of a section of road in India, which, being in front of workshops, was traversed by an engine with rubber tires weighing 6 tons many times daily. This road was formed of broken bricks, and was repaired annually after the rains; however, the year that the traction engine ran over it this annual repair was found unnecessary, as there was not a rut or depression worn in the surface of it. I leave it to the imagination of the reader to consider what would have been the state of this rubbly brick road after a month or so if a traction engine of the same weight with rigid tires had been running over it. To see a heavy engine with rigid tires going up a paved street, breaking every joint, and leaving a zigzag line of cracks between every paving stone after the driving wheels have passed over it, is indeed a painful sight to a road surveyor, and no wonder can be expressed that the opposition to the extended use of traction engines is so great. But it would puzzle the same surveyor to find out where the engine on elastic tires had

been, even if she had followed the same track daily for months.

Experiments were carried out at Chatham to show that elastic tires possessed slight advantages over rigid ones, in fact, so slight, that the money laid out in them had far better be laid out in improvements in the engine itself, such as putting in steel for iron wherever possible, etc.; and these experiments will doubtless be quoted to disprove the arguments I have put forward; so I will briefly state what was done, and what was proved by these trials.

Elastic tires were applied to an engine belonging to the Royal Engineer Department. These tires were made up of segments chemically attached to plates of metal, which were again bolted to the peripheries of the driving wheels. This engine, so fitted, was put into competition with an engine on rigid tired wheels, but in all other respects similar; and, roughly speaking, those who conducted the experiment, considered that the elastic tires possessed $\frac{1}{6}$th or $\frac{1}{7}$th more adhesion, or bite, than the rigid ones; and that this, as I have said above, hardly warranted their cost.

Now it will be observed that the bite question alone attracted their notice. Friction brake, springs, diminished wear and tear of engine, and of highway, were alike ignored; and yet the want of any one of these is sufficient to condemn a traction engine. Even as regards bite, the results observed were so fallacious that they are not worthy of notice. The rubber used was so thin and hard that the surfaces of contact were very small, and the bite consequently very different to what it would have been had the driving wheels been fitted with the best description of elastic tires, viz., solid rubber rings $4\frac{1}{2}$ in. thick; and the surface of the road was in a very favorable condition for the rigid tire, being hard and dry, with a good coating of grit on it. This condition of road is the most favorable one possible for a rigid tire, but such roads are not very abundant, and traction engines with rigid tires have hitherto failed because they are always coming to a stand-still on paved streets, sandy, wet, greasy grass, and all manner of soft roads and grounds. If the two engines at Chatham had been tried over all these varieties of road, the elastic tired engine, bad as it was, would have showed vastly superior bite to the other, and would have had, over and above, all the advantages I have above mentioned as being completely ignored by those conducting the experiment.

ARCHITECTURAL PROBLEMS OF THE DAY.

From "The Building News."

We noticed a week or two since two very different sorts of originality which show themselves in various classes of modern work: one sort sterile, purposeless, and ending in itself; and another fruitful, suggestive, and bearing the germs of future development; and we tried to point out that the valuable kind of originality is not that of the artist who sits down deliberately to produce novelties, but of the one who, having new problems to deal with, inevitably finds, when he has mastered them, that he has arrived at new solutions. There is no lack of such problems at the present moment—seldom perhaps, since architecture first began, have there been so many; and in calling attention to a few of them we may possibly help to turn into a useful channel some of the force which is now wasted in vain and aimless efforts. To arrange in a connected scheme all the questions which occur would occupy, not an article, but a book; we can here only attempt to name a few of them disconnectedly, as they happen to suggest themselves.

The first, and most urgent class of problems, includes those which relate to general design and arrangement. The modern architect has to deal with a multitude of buildings for which no ancient precedents exist; how is he to treat them? Suppose, for example, he is planning a large church, say for 1,500 people, and suppose his clients are so unreasonable as to wish all these people to be placed in sight and hearing of the service, how is he to effect this at moderate cost with architecture worthy of the name? Here alone is a problem, to begin with, which

one man's lifetime would be too short to solve completely. Here is not only an opening, but an urgent need for originality: a case where originality is not merely desirable but absolutely indispensable. And what sort of treatment does it meet with? Nineteen times out of twenty, the problem is absolutely ignored—there is not a single step taken towards its solution. Either convenience alone is attended to, and the result is a "preaching-shed," disguised with a lot of vulgar finery; or art is the one thing followed, and the product is a beautiful church with no fault except sheer unfitness for its purpose. The architect, perhaps, has introduced much novelty into the carving of the capitals; his window tracery is singular and noteworthy; he has even brought from the Continent a tower and spire of extraordinary quaintness; but where the design called aloud for original thought—in its general planning and construction—he has not an idea to give us. Much the same is it with other buildings for public assembly. How should they be treated, when above a very limited size, so as to be successful internally and externally? There are our concert-rooms, like Exeter Hall and St. James's Hall; if they are to be built without columns, how are we to treat them on the outside to make their wide roofs and awkward proportions endurable? If, on the other hand, they are to be built with columns, where can these columns be least objectionably placed, and how, if they are of iron, can they be satisfactorily treated? There are our theatres, the very centres of all that is architecturally false and hideous. How can we make them honest in construction, simple and natural in design, fit for their intended use, and yet capable of yielding a sufficient return for the money invested in them? For those who have the opportunity of dealing with it, here is another problem almost large enough by itself to satisfy one man's ambition. Then again, there are our large railway stations; each of them, in their present state, enough by itself to spoil the finest view into which it intrudes; each of them, like those at Cannon-street, Charing Cross, and St. Pancras, so monstrous in its size, so astonishing in its shapeless deformity, that the mind can fix on nothing else while such an abortion is visible. Is it enough to dot over the walls of such a thing with bits of Gothic detail, and to leave its chaotic mass untouched; to sing songs of triumph over the "wonderful success with which Mediæval principles have been applied to a railway terminus," when the very sight of it a mile off might have filled any Mediæval builder with horror? We are not complaining of Mr. Scott, who, in his department doubtless did what was possible at St. Pancras. What we maintain is, that general design, here as elsewhere, is the first thing that demands attention, though unfortunately the last thing that usually receives it. Is it really essential that these vast stations should be covered in one span? or are the pleas put forward only meant to reconcile the public to a frightful eyesore, and the shareholders to a needless and wasteful expense? Is not the fact at bottom this, that the average engineer cannot understand any greatness except that which is measurable in feet and inches, and thinks that to put up a wider roof than anybody else is to prove himself a greater man? In this case it might be better for all parties to let him satisfy his ambition elsewhere; to find him a piece of waste ground, and pay the cost of erecting on it one truss as wide as he could possibly contrive, and then, having immortalized himself in the only way he can conceive of, to let him act, in his practical works, with an eye to such trivial matters as economy and beauty. But, however this may be, the general arrangement and construction of our larger railway stations presents one of the chief architectural difficulties of the time—one that is none the less truly architectural because it is seldom an architect whose business it is to grapple with it. We might go on enumerating, did space allow, many more types of modern building, each of which is a problem by itself. But a little reflection will furnish our readers with the list, and we therefore pass on to a wider question. What should be the general character and expression of our town architecture? What sort of grand combined effect can be got out of all the diverse designs which make up a modern city, or is there no such effect to be produced at all? Is it possible for us all, working each in his own way, and for his own ends, to make up, notwithstanding, a perfect and harmonious whole, or must we go on, as now,

in discord and confusion, each work injuring other works, and being injured by them? We look abroad, at certain Mediæval cities, and at certain other newly built ones, and see that both, in different ways, have arrived at a grand combined result. The first have done it by picturesqueness and freedom—by bringing out the individuality of every separate building, and emphasizing it by adopting, in short, a vertical type for their street architecture. The second have done it by uniformity and stiffness—by suppressing individual character, by settling every height and width, and projection, according to unalterable rules, by taking up the horizontal principle and imposing it on every one, by obliterating the individual houses, and caring only for the general mass of buildings. Is there any prospect in England of getting the latter system enforced by law? Is it likely ever to be generally followed without such enforcement? and, if not, is not the opposite system the only practicable, even if not the only desirable one? Seeing that we cannot make our streets uniform, is not the only true course to make them picturesque? To answer such questions as these is to do something towards solving the problem of how to produce harmony in our town architecture; how, at last, to make our cities a grand whole filled with beautiful and harmonious parts, instead of a chaos of mutually destructive elements. And where they are answered, either one way or the other, a multitude of other questions suggest themselves. Suppose the uniform and horizontal type of street architecture is set aside as impossible for us. Suppose the opposite type, where every separate building is individualized, proves itself to be the only one on which we can gain any sort of combined result. The first step towards its adoption—towards the marking off of each design from the rest, can hardly fail to be the introduction of a certain verticality into the composition. The heavy cornice is the natural crowning member on the uniform and regular type; when every house is made to range in height, a long unbroken line of such cornices binds the line together into what may be made one grand perspective. But the steep roof or gable is the most attractive finish on the alternative system; standing out against the sky, it marks off, as nothing else can, where the strip of elevation which it belongs to begins and ends. In London, however, the Building Act binds us down, for warehouses, to a certain limit in pitch; and in private houses, rooms wholly in the roof find little favor. It is, therefore, a matter for consideration whether steep roofs are essential to a picturesque street architecture, and especially to one developed on a Gothic basis; whether we can overcome, in some cases, the practical objections to them, and in other cases, dispense with them altogether.

Descending further into detail, the modern architect is met by unsolved, or, as yet, but half solved problems at every step. We can here only indicate a few of them in the briefest manner. What, for instance, is he to make of wrought-iron girders? May he use them, say, to carry the wall above a shop front, and, if so, is he to show them or conceal them? If he shows them, how far can they be made to harmonize with the brick or stone arches in the rest of the elevation? What, again, is he to make of iron roofs, and how is he to make their wiry lines agree in any way with the broad wall surfaces on which they rest; and how is he to finish his iron work—by painting, or bronzing, or enamelling—so as best to bring out its metallic character? We could point to examples where something has been done towards answering each of these questions; but in the average of recent work they scarcely seem to have had a thought. Then, in a very different department, how is the London architect to protect his work from London smoke? Of course, if he feels that it is not worth protecting, and is satisfied with Bath stone and stock bricks, he escapes this problem. But, in the opposite case, what are the best materials to use, granite and marble, terra-cotta, or glazed bricks? And how should his design be modified to suit each of them? Next, having settled how to make his works smoke-proof, he may consider how to make them partially or wholly fire-proof. As far, at least, as the staircase is concerned, this ought to be done in every house—not, if we may trust Captain Shaw, with stone, but with some material that fire will no more break than burn. Then there are the questions of how to ventilate houses; how to warm them more thoroughly and less wastefully; how to get

the plumbers' work a litte nearer perfection, and at least to keep the water-pipes from bursting every frost; how to improve the design of a multitude of details, such as chimney-pieces, grates, and ironmongery; how to use sash-windows and plate-glass with good effect in a Gothic building, or what to substitute for them; how, in short, to adapt old styles to modern uses, and to bring into the field of architecture the waste and uncultivated deserts which now stretch all around and wait to be reclaimed. We do not pretend to have indicated a tithe of the problems which are pressing for attention. These, however, may be enough to show that there is no want of subjects just now for thought, and that the designer who wishes to be original is not obliged to concentrate his talents on the production of some new form of moulding or chamfer-stop.

TRAMWAYS FOR CITY STREETS.*

By JAMES A. WHITNEY, M.E.

Of city pavements now in use there is not one without some manifest advantage, and none without some drawback, the amelioration of which would be a great public benefit. On Broadway we have the firm Belgian, best of all in its capacity for resisting abrasion, but with its interstices forming inequalities in the surface which result in great wear and tear of vehicles, increased labor upon draught animals, and an almost unending uproar; for it must be remembered that a single omnibus or cart in passing over one mile of this pavement is subjected to more than 60,000 concussions, or in an ordinary day's travel of, say, 30 miles, to nearly 2,000,000. The noise of the Belgian pavement, and to a great extent the severity of the concussive action upon it, is done away with in pavements formed with wooden blocks, which also, in a considerable degree, especially with light loads, lessen the draught. But pavements of wood, although found in Chicago to endure for 8 or 9 years without relaying, are worn down at the rate of more than $\frac{1}{2}$ in. per annum under the crushing impact of the traffic in New York. Attention is, therefore, very naturally turned to the possibility of securing, in a measure at least, the same advantageous characteristics combined with greater durability. Even the old cobble-stone, perhaps the worst of all in every respect, save the security of foothold for horses, is for this one merit still retained between the tracks of our street railways, and a hint of the manner in which the paving of city streets may be best fitted for the duty required of it is given by the custom common among cartmen of driving the horse between the rails with at least one wheel running upon the track. To provide a pavement which will afford the firmest grip for horseshoes, and at the same time the smoothest running way for wheels, would, as nearly as is possible, meet the requirements of ordinary vehicles in traffic and transit in the city streets. This for a brief period is said to have been realized by an enterprising omnibus company in London, who changed the gauge of their vehicles to correspond with that of the tramway then recently laid down in the English capital. In this case, however, the parties, although they succeeded in showing the utility of the iron wheelways constituted by the rails, were promptly estopped by an injunction from interfering with the exclusive right to the track vested in the tramway company.

Incread ease of draught and security to draught animals, as already intimated, are the two all-important essentials of a superior pavement. The former not only enables a given number of horses to draw a greater load at the same speed, or the same load at a more rapid rate, but, from the nature of the conditions necessary to secure this, also insures a diminution of noise and decreases the deterioration of rolling-stock. A good hold for the feet of horses manifestly permits the smoothness of the running way to be utilized to the utmost, either for speed or power applied to propulsion, and also avoids the great liability to sudden and serious loss from the slipping and falling of horses upon the pavement. We may

* Paper read before the New York Society of Practical Engineering, Jan. 18, 1871.

therefore here consider, first, the relative values of different kinds of pavement with reference to the economy of draught power; second, the varieties best adapted to provide the requisite foothold for the animals by which the power is furnished; and third and lastly, the most feasible method of combining the best examples of the two in the least costly manner, and with the least interference with pavements already approved as in actual use in our streets.

The resistance of roadways or pavements made of different materials, and according to various plans, has been the subject of very careful research, especially abroad, and the results attained come verified as the dicta of the most eminent English engineers. According to these, a tractive power, equal to 100 lbs., continuously exerted, will draw on a level road as follows: A common gravel, 15 cwt.; macadam, 2,700; granite pavement, 3,500; broken stone surface laid on an old flint road, 3,400; same on a rough stone pavement, 4,800; wood pavement, 5,475; a stone pavement of more than ordinary uniformity, 6,700; and a common iron railway track, 27,600 lbs.

Of these examples, the gravel road may be taken as an equivalent to an average country road in good weather, and is of no interest in this connection. The macadam, still used in suburban districts, but objectionable from the grinding of its surface into dust, need not, for the reason just indicated, be further considered here. The granite and stone pavements, as will be seen from the above data, gave results superior to the macadam as far as traction is concerned; but when laid in blocks possessed all the manifest defects of our present stone pavements; and when of broken stone, laid on sub-pavements or foundations, those inherent in the macadam. The wood, affording, when properly laid, the surest footing for horses, shows also very high merit in point of non-resistance to tractive force, but, as several times intimated in the present writing, fails in point of durability. This, a serious defect, can only be partially remedied by the most judicious selection of material and the greatest care in preparing and laying down the blocks. The permanence of wood pavement may, however, be measurably increased by causing the abrading action of the wheels to be received by the best of all materials for the running or permanent way of wheeled vehicles. In other words, by iron tramways laid flush with the street surface, and so constructed that, while affording projections to keep horses from slipping upon them, smooth longitudinal ways will be furnished for wheels to run upon. The advantage of this is evident when we recall the enormous disproportion between the weight drawn by a tractive force of 100 lbs., on an iron track, and that moved by the same power on any other of the various kinds of pavement previously herein specified. Estimated roughly, this difference is so great, that one pair of horses can draw a load over a smooth iron tramway, which, on an ordinary macadam or turnpike, would require from seven to nine pair of draught animals.

Reasoning *à priori* from the basis just presented, it would seem that the best results would be achieved by providing a street with iron tramways, preferably two, for travel in opposite directions, the portion of the surface not occupied by the tramway tracks to be covered with a wood pavement. This latter, nevertheless, would not be essential, and in most instances it would, doubtless, be desirable to leave the present pavement undisturbed, except so far as absolutely necessary in laying the tramways.

In the preceding remarks, the writer has set forth, in general terms, the elements of a new system of street improvement, and the principles upon which the same is based. It is the invention of Samuel D. Tillman, well known as Prof. of Technology in the American Institute, and Chairman of the Polytechnic Association. With regard to the precise manner in which the improvement is to be carried out in practice, the writer cannot do better than to quote, in brief space, Prof. Tillman's own description of its peculiar and essential features:

"Employing iron as the material for the wheel-ways or tramways, I would," he says, "cast it in hollow blocks, so as to be interlocked, and its face could be provided with a series of smooth raised surfaces, alternating with impressions or indentations; and the raised surfaces could be so arranged that the wheel would be constantly sustained on a true grade by rolling over one raised surface, which should touch the middle of the tire, or

rolling over two raised surfaces, which, either simultaneously or alternately, would give a bearing to the wheel-tire near its sides. The transverse depressions thus formed allow the toe-cork or fore part of a horseshoe to sink below the raised or grade surface, and by means of such surfaces the horse would find a sufficient bearing against which to exert the leverage of his foot. A pair of iron paths, each about 1 ft. wide, and placed $4\frac{1}{3}$ ft. apart, would provide a tramway suitable for vehicles of various widths, embracing the pleasure carriage, cart, lumber-wagon, and omnibus, and a pathway for a pair of horses between such tracks. The tramway could be made of hollow cast-iron blocks, each about 1 ft. long, with a projection on one end and a recess on the other, so that when brought together and interlocked, the pressure on the edge of one block would be transferred to the centre of the next. Such blocks could be laid directly on pure sand, or be filled in from beneath with wood, and laid on a perfectly solid and smooth foundation. The tramway could also be constructed of longer wrought-iron or cast-iron plates, having longitudinal ribs or webs underneath to strengthen them ; each resting securely, by means of spikes, on one-half of the top of a wooden post set in the ground, and reaching below the action of frost. This plan would give a permanent pathway for the wheel, independent of that for the horse, and also would be unaffected by any changes which the surrounding earth might undergo by the action of water or frost. The face of such tramway could be composed of alternating smooth elevations and depressions, of a series of narrow ribs running longitudinally, or of a smooth surface having on it one or more lines of elevations and depressions, so arranged as to provide a foothold for horses, and, when placed on the edges of the tramway, to allow wheels to pass obliquely over without sliding."

It will be seen that the precise means employed in carrying the system into practice may be modified in many ways, but those which are thought preferable are thus described : each block is formed with two lateral or wing-like portions and a central and tongue-like portion in such a way that when fitted in line with each other the central tongue of one will fit between the wings of the other. These mutually support each other against superincumbent pressure, even when exerted at the edges of the blocks. This support is, furthermore, aided in a degree by lugs, provided in such manner as to jut into recesses or seats suitably arranged in the edges of the adjoining block. The upper surface of each block is grooved in such a way as to afford a foothold for horses, and at the same time, from the disposition of the grooves and of the raised surfaces between, furnish a bearing which shall be continuous upon some part of the periphery of the wheel passing over the same. The under side of each block is made of somewhat cellular form by longitudinal and transverse partitions, which constitute braces to give the requisite strength against vertical pressure, and also by their hold upon the sand, concrete, or other foundation, to prevent lateral displacement of the track. It is also proposed by the inventor to apply the same system of iron paving-blocks to the construction of pavements covering the entire surface of the street in cases where a pavement of such character is preferred.

Such, we remark in closing, are the essential features of an improvement by which it is proposed, at a fraction of the cost of any kind of pavement in use, to increase its utility many times by diminishing the power of draught required in moving vehicles through the street, and also to promote the greater permanence of the pavement itself, by causing the abrading action of the wheels to be received by the smooth and comparatively indestructible metal, instead of by granulating stone or soft or slowly decaying wood.

The Pacific Steam Navigation Company, whose vessels run direct between Liverpool and the West Coast of South America, are providing their new steamers with Yarrow and Hedley's screw launches, in order to reduce the time occupied at the ports touched at, by keeping up a rapid communication with the shore.

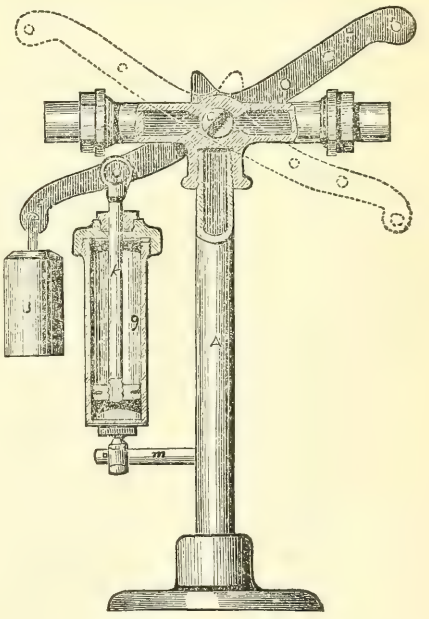
A manufactory of locomotives in Vienna has undertaken to furnish 80 locomotives on an order from Strasbourg.

IMPROVED METHOD OF REGULATING THE OPENING AND CLOSING OF COCKS.

From "The Mechanics' Magazine."

The principal object of this invention, by Mr. T. Penn, of Westbury street, Clapham, is to regulate the closing of water-closet and other cocks to give time for a certain quantity of water or fluid to flow through the cock from the time it commences to close until it is entirely shut off, at the same time preventing the cock from being injured by suddenly jerking it open; this is accomplished by affixing a suitable lever to the shank or stem of the cock made to extend out on both sides of it; to one end of this lever is attached a rod of brass furnished with a piston on the opposite end of the rod, and made to work in a tube or small cylinder of oil or other fluid, closed at one end and furnished with a screwed cap or cover at the other, through which the piston rod works; this cap is provided with a stuffing-box to make a joint around the rod. The piston is furnished with a small hole for the passage of the oil or fluid from one end of the cylinder to the other. The ease with which the cock opens or closes will depend upon the size of the hole in the piston for allowing the oil to pass from one end of the cylinder to the other when the cock is being opened or closed. The cock is opened by moving the opposite or same end of the lever to which the piston is attached, and may be worked or moved through the medium of bell cranks, rods, or cords and pulleys, or by taking hold of the lever direct. The passage of the oil from one end of the cylinder to the other through the openings in the piston will prevent it from being suddenly jerked open owing to the resistance given by the oil; a weight is attached to the end of the lever to which the piston is affixed for closing the cock by pulling the lever down; the size of the weight is regulated to suit the time in which the cock is to be closed. The lever to which the weight is suspended is provided with holes or notches for hanging the weight upon it at the proper point to get the required power for closing the cock at the proper time.

This improvement is particularly applicable to cocks employed in connection with water-closets, which can be regulated to give ample time for the water to flow after the pan is up to hermetically seal it; they can be fixed and worked in any position, and arranged without being connected to seat to interfere with its being removed for repairing the closet, or other purposes. The cylinder of oil or fluid in which the piston works is affixed to a bracket or standard placed in any suitable position for connecting the piston to the lever on the cock stem, and connected with lever and bracket so that the cylinder will accommodate itself to any position to suit the working of the lever. If desired, instead of making a hole through the piston for the passage of the



oil or other fluid, the piston may be made slightly smaller than the cylinder or tube for allowing the oil or other fluid to pass from one end of the cylinder to the other for giving resistance in opening and closing the cock for the purposes before stated.

Fig. 1 represents a cock mounted on a standard partly shown in section, and a sectional view of the oil cylinder.

A is a standard, to the top of which the

stock B of the cock is attached, as represented. C is the cock to which is attached the cross-lever E F; to the E end of the lever is attached the weight J, for drawing the cock close or shutting off the supply of water; to the same end of the lever is attached a piston rod *k*, working in the cylinder *g* through a stuffing-box, as represented; this cylinder will be filled with oil or other fluid if desired; the lower end of the rod *k* is furnished with a piston *f*, through which is made a suitable sized hole *h*, for allowing the oil in the cylinder to pass through it to regulate the closing of the cock; the piston *f* has a groove around its circumference for receiving a ring of leather or any other suitable substance for packing purposes; *m* is a support attached to and projecting from the standard A for carrying the cylinder *g*; the cylinder is so attached to this stem that it takes any position to suit the working of the lever E F. The cock is represented closed, and in order to open it, the E end of the lever may be drawn up by any suitable handle, rod, or cord, for working the same, or by drawing the F end of the lever down until it reaches the position denoted by the dotted lines in Fig. 1, when the cock will be full open for the passage of water, as described by the darts. The cock is then closed by the weight J pulling the lever down, which in the meantime forces the piston *f* to the lower end of the cylinder; the movement of the piston downwards is regulated by the resistance of the oil in the cylinder passing through the opening *h*, in the piston *f*; the time the cock C is kept open will depend on the size of the hole *h* for the passage of the oil, the larger the hole is the sooner the cock will close; the proper diameter of it will have to be ascertained by practice, for the various size cocks and quantity of water to be discharged in a given time.

ROLLING AND SWING BRIDGES.

From "The Artizan."

It not unfrequently occurs that it is required to erect a bridge across a river, or estuary, where the conditions of the locality render it necessary that a portion of the bridge should admit of being opened, or temporarily removed, in order that shipping may pass it, and the construction of such a bridge calls for the most careful consideration, both in the designing and execution of the work; hence we propose to offer a few remarks on the principles of these structures, such remarks being chiefly of a practical character.

There are several ways in which a bridge may be opened: thus the roadway may be withdrawn, or rolled backward towards the land, or it may be caused to revolve upon a centre, thus altering its position from being at right angles to the direction of the stream for one parallel to the same, or it may be caused to rise vertically about a centre fixed upon the pier. Of these three classes of bridges, the first is termed a rolling bridge, the second a swing bridge, and the third a bascule bridge; and the question to be determined is, which description of structure is best suited for the work set out for it.

The desiderata in opening bridges are, durability of parts, rapidity in opening and closing the bridge, and minimum of force required to effect the same. The importance of the first point is rendered more distinct by comparing an opening bridge with one which is permanent in its position. In the former case it is usually absolutely necessary that the bridge should, during certain periods in the day, be open, to allow the continuance of traffic on the river or estuary which it spans; hence if the working gear be out of order, so that the structure cannot be readily opened and closed, it must be kept open until it is again in a position to work with ease; therefore, while undergoing repairs, it is useless as a bridge, if those repairs are being made upon the moving gear. Rapidity in opening and closing the structure is very necessary, in order to reduce the loss of time due to stoppage of traffic to a minimum, for it must constantly occur that either the land traffic is stopped to accommodate that on the water, or *vice versa*.

The third requirement refers to the amount of force requisite to put and maintain the bridge in motion while open-

ing and closing, and, as a matter of course, the less power required, the simpler will the machinery be; the cost of working and wear and tear being proportionately small, hence the liability to derangement of the working parts is also small.

We will now proceed to consider *seriatim* the different descriptions of opening bridges, to which we have above referred, commencing with the rolling bridge.

The rolling span of an opening bridge is so arranged, that, when requisite, it can be wheeled or rolled back in a line parallel to the direction of the length of the bridge, so as to pass over or under another portion of the structure, or on to the land, thus leaving the space clear which it occupied when resting on its piers, and doing duty as a bridge. In such cases, the structure will usually be made to move upon four or more rollers, two of which are fixed to the shore end of the rolling girder, and, like ordinary carriage wheels, travel upon rails, while the others are supported in fixed frames or pedestals, the girders of the bridge resting upon them and passing over them, while rolling back and forward. To this description of structure there are many very grave objections, objections which theory will fail to discover, although after they are rendered conspicuous by practical experience, the defects giving rise to them may be accounted for by reasoning on the conditions under which these masses of matter are required to be put into motion. In the first place, it will be observed that there is a very great load on each roller, especially when we find only four rollers to sustain the entire weight of the bridge. Assume, for instance, such a work to weigh about 100 ons, which would correspond for a railway bridge to about a 70 ft. span, then there will be 25 tons weight on each roller carrying the bridge, and from the form of the bridge and its mode of motion, its progress is necessarily unsteady from its own vibration, which is increased by any inequalities of the surface upon which it runs, and also by starting or jerking of the propelling machinery.

As we have above stated, a part of the bridge must be allowed to rest on rollers in fixed pedestals, hence the lower surfaces of the bottom flanges of the girders are those upon which the rollers revolve, and any unevenness in such surfaces must very materially add to the amount of force required to keep the structure in motion, and if the flange be curved, it will of necessity involve the addition of extra force, either when opening or shutting, to propel it up the incline, produced by its own curvature. Moreover, a brief consideration will show us that such a curvature in the girders of a bridge cannot possibly be avoided, for if we make the bridge with a dead plane surface to its bottom flanges, it will deflect with its own weight; and even if we allow, for the sake of argument, that the bridge could be made with such a "camber" that its own weight will exactly bring it down to a straight line when on its bearings, then again whilst in the act of rolling its deflection would vary, for the distances of the points of support must vary, the rollers supporting the ends of the girders being fixed to and travelling with it, whilst the others retain their positions in relation to the fixed piers, so that when the rolling span is first started from its fixed bearings it has a long overhang, and there is a short distance or length of span between the fixed and travelling rollers; then as the bridge progresses in opening, this length of span increases, accompanied by the decrease of overhang, and a corresponding change occurs in the form of the girder. A similar but obverse change of form occurs in closing the bridge. This, then shows that there is a cause which cannot be obviated, always giving rise to excessive resistance to motion on the part of rolling bridges, which, we may observe, is much aggravated by the changes produced in a bridge by the vibratory effects of passing loads, and more especially of railway trains. The extent to which these disturbing causes affect rolling bridges may appear somewhat astonishing to those who have not been much acquainted with them in a practical sense, but when we observe serious mistakes in calculations connected with such matters, we look closely for the causes, and they often lie nearer the surface than might have been anticipated. To bring the matter more clearly forward, we will have recourse to figures obtained from actual trials. The first point to be determined is the amount of tractive force required to move the bridge; here it might seem that railway practice should furnish us with the requisite data; but, to be on the safe side,

we will allow a tractive force of 20 lbs. per ton of load ; then for this we have, taking the rolling span of the bridge as weighing 100 tons, $100 \times 20 = 2{,}000$ lbs., or say roughly, 1 ton. This would be moderate enough, but we find in practice it sometimes requires three or four times as much, and in one instance there was actually six times the calculated tractive force applied to a rolling bridge before it would move, and then it went but slowly and spasmodically, notwithstanding that the bridge was well constructed and carefully erected. The excess of force requisite to propel the bridge was, of course, absorbed in overcoming those obstacles to motion, to which we have referred above.

Under these circumstances it wou'd seem that where they can be avoided it is exceedingly unwise to construct a rolling bridge, there being so many objections to it ; but, of course, where the only available room lies in the line of the bridge, there is no option, and this class of work must be had recourse to.

The next bridge to which we shall refer is that on the "bascule" principle, being that which opens upward, as it were, like a box lid on hinges. This kind of structure answers passably well for small light spans, but when large, is objectionable on account of the power required to raise the weight, and also on account of the resistance of the wind to any opposite movement of a large surface against it.

The last arrangement to which we desire to call attention is that which has given the greatest satisfaction in practice, viz., the swing bridge, which opens by turning sideways, moving from its normal position across the stream to one parallel, or nearly so, to its direction. In this arrangement the bridge revolves upon a turn-table similar in construction to those used on railways, and is, of course, properly balanced, so that its weight may be duly distributed on the working parts of the turn-table.

By adopting the swing bridge, to avoid those great resistances to movement which are so fatal to practical utility of the rolling bridge, there is no tractive force required to produce actual removal of any portion of the structure, in the strict sense of the term ; for the centre of gravity of the opening span, or swing portion of the bridge, remains unmoved. It is located, if properly balanced, in the centre of the turn-table when the bridge is closed, and it occupies the same position when it is opened; there has, consequently, been no actual transference of weight from one site to another, and the only resistance which has to be overcome is that due to the friction of the rollers in the turn-table, and the centre upon which the bridge rests ; and that this may be reduced to a minimum is evident, from the fact that at the present time there are many turn-tables in actual use, which, when loaded with 60 tons, in addition to their own weight, are easily caused to revolve by one man acting at a distance of 25 ft. from the centre. Thus it is evident, that by improving the turn-table of swing bridges, we may fairly anticipate getting a structure as perfect as is practically possible to employ, where it is necessary that a bridge should open and shut ; and in this direction we should strongly advise those contemplating the erection of such works to turn their thoughts, as the rolling bridge has in every case in which it has been used, proved a comparative failure, whereas swing bridges have generally served their purpose well, and the superiority of the latter evidently does not rest upon perfection of workmanship, but is due to accuracy of principle.

The trunnion piece of the fourth 35-ton naval gun was forged in the Royal Gun Factories lately, the mass weighing upwards of 10 tons, being manipulated with great facility under the 12-ton Nasmith steam hammer. The magnitude of the operation will be better understood by the fact that the tongs used to wield the heat are 15 tons in weight. Twelve of these great guns are in course of manufacture, and the department has received an order for twenty 25-ton guns of 11-in. bore, similar to the half-dozen which were proved at the butts lately with 600 lbs. projectiles.

Mr. Ayrton states that none of the methods used for preserving the stone of the Houses of Parliament has been completely successful, but that of Mr. Szerelmy has answered best. Further experiments are being made under scientific direction, to prevent the further decay of the stone, and it is hoped they will be successful.

THE CORROSION OF IRON.*

Formerly it was assumed that iron was subject to rapid corrosion when immersed in water, or exposed to the alternations of the water and the atmosphere, and the every-day experience of constructors seemed to confirm this opinion. Wrought-iron bolts in wooden dams and similar places and in works wholly under water, frequently rapidly oxidize. Cast-iron water-pipes in city streets are frequently found greatly corroded ; and cannon and shot immersed in sea-water for half a century, and sometimes less, have been found with the mass of metal entirely changed from iron into plumbago, or deeply pitted by oxidation.

During the earlier discussions of the subject, the inquirer was frequently staggered in his belief in the generally received opinions, by finding both wrought and cast iron which had been immersed many years but slightly oxidated, and wholly unchanged in its structure.

The cannon of the "Royal George," which had been submerged half a century, when first taken out were so soft that the metal could be cut with a knife, but immediately hardened on exposure to the air, and were again fired. Some muskets and cannon, sunk in lakes Erie and Ontario during the war of 1812, were, forty years afterward, found to be but slightly rusted.

An iron steamer, the "Aaron Manby," which was launched in 1822, and kept in constant use for twenty years, was carefully examined, and no signs of corrosion found; and, ten years later, it is stated that she had required but small repairs for the whole period.

William Fairbairn also cites many cases where iron ships, which had been 10 to 15 years in salt water, showed no corrosion.

This subject was much discussed in England in 1850, and the unexpected absence of corrosion in wrought-iron ships, even on the interior surfaces and iron parts, was then attributed to the vibration of the metal, as was noticed on comparing the amount of the corrosion of railway bars in the track with those laid outside of it.

Plumbago was obtained from cast iron immersed in acidulated water in 1822, and 40 years later Dr. Calvert produced the same result by placing it in sea and foul water.

A dozen years earlier, Mr. Mallett reported his well-known experiments on the corrosion of different kinds of iron in pure and foul atmospheres, and in clear, foul, acidulated, and salt waters, and arrived at the following general conclusions:

That iron exposed to water holding air in combination corrodes on the surface either uniformly or in places, by rust or by the conversion of the iron into plumbago, and that corrosion depends upon the want of homogeneousness of the surface, or in its density or hardness, or in the combination of the carbon with the iron.

This subject was very thoroughly discussed by some of the most eminent engineers of the London Society in 1862, and numerous cases were cited both of corrosion and its absence in iron under water, and the causes explained.

The examples then stated, and numerous others, showed that cast-iron of a particular description corroded rapidly, or changed its structure, by a few years' immerson in foul or salt water, while other irons were entirely unaffected when exposed in the same way for 20, 30, and 40 years.

In the same structure, as in the case of the iron gates of the Sheerness Dock, three pairs of gates had resisted the action of salt water for 40 years, and a portion of the fourth pair, put in several years later, had been much softened and injured by its exposure.

Several of the leading engineers instanced numerous cases of square cast-iron piles, standing partly in and partly out of salt water, and a portion alternately wet and dry at each tide, which, after periods of 18, 24, and 31 years, and intermediate periods, showed no signs whatever of corrosion or change—"the square angles of the iron were as sharp as when they left the foundry."

Mr. Simpson, the past president, said that in his practice he used great care in the selection of the iron, and such iron was practically incorrosive.

* From a paper read before the American Society of Civil Engineers by the Hon. Wm. J. McAlpine, C.E.

The members stated, that wherever this corrosion or decomposition had occurred, it was wholly due to the quality of the iron. The engineer has, therefore, only to select that of a proper quality to insure durability.

My own experience and examinations, so far as they reach, confirm these opinions.

Cast iron, to resist corrosion to its greatest extent, should be as hard as the case will admit, of an even, close grain, and with the carbon combined and not in the form of graphite. Impure, soft foundry iron will corrode rapidly; close-grained gray iron, of an even texture, will resist corrosion in the most exposed places without sensible injury, and white iron of good quality may, for all practical purposes, be considered as imperishable in such situations.

Care should also be taken not to place iron in contact with other metals, so as to produce galvanic action.

It is well known that many cast-iron water mains have corroded greatly, not only externally but internally. In the latter case, the oxidation sometimes takes the tubercular form, where the rust is collected and aggregated in hard knobs.

In the early manufacture of water-pipes, they were often made from the worst quality of metal; it could hardly be called iron, but was a composition of cinders, sand, scoria, and iron of the softest kind, loose-grained, and in large crystals; indeed, precisely such a mixture as would offer the least resistance to corrosion.

Water-pipes placed in the streets of a city in earth alternately wet and dry, and saturated with mephitic gases from sewers and gas-pipes, are exposed to corrosion, more than under almost any other circumstances, and, if made of the material just stated, will be destroyed, where those of a proper quality of metal would endure a very long time. The internal corrosion, however, where the iron is exposed only to the action of pure water and a small amount of air in combination, will not occur to any appeciable degree, if the iron is of the proper quality.

The strength of cast-iron pipes, of the usual thickness, is so far beyond the pressure of the water and occasional percussions, that the manufacturers seem to think that the weakest metal will answer; and the engineers have not yet, in their specifications and inspections, required enough care in the selection of the metal best calculated to withstand corrosion.

INCRUSTATION IN STEAM BOILERS.

From "Engineering."

At a recent meeting of the Institution of Mechanical Engineers, a paper was read "On Whittle's Plan for Preventing Deposit and Incrustation in Steam Boilers," by Mr. George Addenbrooke, of Darlaston. The object of this plan is both to free boilers entirely from incrustation, and also to render harmless the impurities contained in the water, and prevent them from so thickening the water in contact with the heating surface of the boiler plates as to interfere with the due escape of the steam generated. This object is accomplished in a ready, inexpensive, and effectual manner, by placing loosely inside the boiler a lining composed of thin iron plates, extending over the entire heating surface of the boiler nearly up to the ordinary water level, with a uniform space of a few inches left between the boiler plates and the lining, for the circulation of the water. In the bottom of the lining are made openings, or a single long slot, round the edges of which the lining plates are turned up to some height, so as to prevent the mud that collects inside the lining from passing out through the openings with the circulation of the water. The effect of adding the lining inside any boiler is that a very active circulation of the water is produced; the water in the narrow space between the lining and the boiler plates becomes heated by contact with the heating surface of the plates, and forms a continued rising current, which passes over into the interior of the lining, carrying with it all the earthy matter that has been precipitated by the evaporation of the water. In the comparatively quiescent water inside the lining, this earthy precipitate then settles down to the bottom of the lining, where it remains

harmless in the form of soft mud, which never comes in contact with any part of the boiler heating surface, and is got rid of by blowing off at regular intervals, as it accumulates. The lining has thus the effect of separating the mud from the water, and rendering it harmless by simply mechanical means; but in the case of using chemical means, by employing boiler "compositions," the mud is dissolved, and continues mixed up throughout the water, which consequently becomes so much thickened as to cause injury to the boiler by overheating of the plates. The uniform space between the lining and the boiler plates is preserved by short studs at suitable intervals, upon which the lining plates are cottered, and any portion of the lining can readily be removed, whenever desired, for the purpose of examining the boiler plates at any part. Not only does the rapid circulation of the water over the heating surfaces prevent the formation of any incrustation upon the boiler plates, even when using very bad water, but in boilers previously incrusted with a considerable thickness of scale, the application of the lining has resulted in the gradual and complete removal of the incrustation, the scale being washed over in fragments into the inside of the lining. Some of the boilers fitted with this lining have purposely been kept in constant work, day and night, for more than two months, with feed water containing a large proportion of earthy matter, and without blowing off; and on subsequent examination the boiler plates have been found clean and free from incrustation, while a large accumulation of mud was deposited in the interior of the lining, so much in excess of the quantity of mud to be removed from an ordinary boiler as to prove clearly the value of the lining in separating the deposit from the water. Considerable economy of fuel is found to result from the more perfect communication of heat to the water in the boiler, consequent upon the clean heating surface, and the continuous active circulation effected by the lining. Specimens were exhibited of the soft mud collected in the lining in different boilers, and of the hard scale formed upon the surface of the plates in the same boilers previous to the application of the lining.

CENTRING.

From "The Mechanics' Magazine."

In the present age of engineering many of our permanent structures require during the progress of erection the aid of a temporary support, which, except for the nature of the materials employed in the two cases, does not very much differ from the work of construction with which it is for a time intimately connected. Any one who bestowed the most cursory attention upon the temporary works which for three or four years existed at Blackfriars, is aware that more material was used in them than would have sufficed to build a bridge over the Thames. According to the character of the temporary support, so is it named. The term centring originally and strictly applied only to arch bridges, but in its wider signification it is employed to designate a variety of staging, scaffolding, and timber supports. Centrings may be of all sizes, from the diminutive specimens used in building sewers and drains to the gigantic examples required for our large metropolitan bridges and station roofs. In the one case they consist solely of a few boards nailed together; in the other, they assume the dimensions and proportions of a large truss, demanding a considerable share of engineering skill and practical ability in order to effect their construction with safety and economy. Let us consider for a moment the case of the stone bridge over the Dee, near Chester. Its span is 200 ft., and, with one exception, it is the largest stone arch in the world. The weight that the centre for this bridge must have had to support, before the arch was finished, the key-stone driven in, and the wedges slacked, must have been enormous. There is an immense difference in this respect in a structure of stone and one of iron. In the former all is dead weight; the strength, in fact, lies in the weight. There is no assistance to be derived from taking advantage of the strains of compression and tension, in the manner in

which they can be provided for in the different members of an iron bridge or roof. In a word, there is no room for what is known as conversion of strain in a structure of stone. When the example consists of an iron bridge or an iron roof, there are various principles that may be adopted according to the especial circumstances of the case. Thus it is possible, by the selection of a particular design, to lighten the load that has to be borne by the centring. This is out of the question when stone arches have to be dealt with. The centres must then be constructed of the maximum strength, as not a particle of strain is taken by the permanent structure itself until the arch is keyed in. The designing of centring, and the timbering necessary to temporarily support tunnels, sewers, and bridges while their construction is in progress, is a particular branch of engineering. Many members of the profession who would be quite in their element in proportioning the scantlings and dimensions for a bridge over the Thames, would be quite at sea, to use a common phrase, if they were called upon to place *in situ* the timbering necessary to support the intended brick-work or masonry of a large sewer. On this account alone, a brief notice of the whole subject will not be without interest to our readers.

To commence with a familiar case, let us suppose that it is required to lay a sewer of moderate size in the ground at a depth of about 12 ft. or 14 ft. from the surface. If there is plenty of room on each side available for excavation, the trench or gullet is taken out pretty widely, and the quantity of timbering or shoring up necessary is reduced as much as possible. But, on the other hand, where from existing traffic or other causes, it becomes imperative to limit the lateral extent of the excavation to the minimum amount, the sides of the trench must be taken out "plumb," or as nearly so as the natural inclination of the ground wil admit. Abundance of examples in which this method is adopted are witnessed in the everlasting ripping out of the streets and main suburban thoroughfares of the metropolis. The trench is first taken out as neatly and cleanly as if the sides had been sawn through by a gigantic saw. They are then lined longitudinally with sheeting boards, and cross struts carried at proper intervals from one side to the other. At the proper level, where the arch of the sewer is to be turned, the centres are fixed. These are generally made for small examples in lengths, so that after a given length of the crown has been got in, the centre is removed, another length of arch turned, and so on until the whole work is completed. All the timber used in these instances can be made available for the next job of a similar character, as there is little or no damage done by bolt holes, straps, or other means of connection employed in larger and more pretentious works. The centres would not answer again unless the shape of the crown of the arch was the same, but they could be readily taken to pieces and put together again. One of the greatest difficulties to be overcome in the erection of all temporary staging and centring is to fix it in such a manner that, while it affords a firm support to the permanent work in progress, it shall not interfere with the men engaged in their various occupations. Thus, not only is there a considerable amount of skill required to design the supports so that they shall be strong enough for their purpose, but there is also a need of some ingenuity to arrange them so that they shall not prove an obstacle to the rapid progress of the operations. There is nothing more annoying to good experienced workmen than to find themselves hampered in every direction by the erection of posts, struts, and braces, which ought to have been placed in altogether different positions. Even in instances in which the staging is arranged in the best manner possible, it is not to be expected that the same amount of work will be got out of the men which they would perform were they excavating or building in the open. An extra price is invariably charged by contractors when the work to be done partakes of the nature already described, as men cannot get through their fair allowance of a day's work in narrow and restricted sites.

Passing on to those cases in which the staging and centring assume the proportions and forms of large temporary constructions, there are two particular examples which present themselves, and which are susceptible of separate treatment. In the one there is no obstacle to the free employment of a moderate amount

of strutting and bracing below the level of the soffit of the work. In the other the timbering must leave a perfectly unencumbered headway underneath. The strength of trussed centring will always be proportional to the depth, so that the more this dimension is reduced the weaker will the truss be. Fortunately this principle of construction admits of the reduction of depth below, the ordinary ratio of that dimension to the span being counterbalanced by the relative arrangement of the different members. Still the prohibition to give a certain depth to centring and staging has before now proved fatal to the adoption of particular types of bridges. It was so in the case of the original design for the "Britannia" Bridge over the Straits of Menai. The authorities, rightly or wrongly, insisted upon the waterway of the Straits being maintained intact during the erection of the bridge, which was an impossibility if any staging or centring were to be employed. The same duty is therefore frequently demanded of a centring as of a permanent structure which it serves for a time to support. It has to carry the load above, and leave as free a passage as possible below, and it becomes necessary to dispense with as much of the depth of the truss constituting the centring as can be done without. The centring used in the lining of portions of the tunnel lately completed under Mount Cenis furnishes a very good example of this method.

This plan is especially requisite in designing centring for tunnels, as the headway is always necessarily limited so as to reduce the excavation to a minimum. In spite of the almost universal application of iron to building purposes, timber still remains the favorite material for temporary works. It is true that iron centres have been used in a few instances, but they have made little or no progress as a substitute for the older material. In this respect, they are not nearly so far advanced as iron piles are with regard to those of wood. The fact is that timber is always to be obtained on very short notice, and can be cut and fitted so as to be adapted to different situations with far greater facility than any other constructive agent. After being in service in one particular work, it can be utilized again in another. Not exactly to the same advantage, for frequently it is so damaged and injured by bolts, spikes, and other means of fastenings, that it is only fit for being cut into small scantlings. However, even in this state it can be made useful, and can be sold for something. The magnitude of the work will be the real guide to the contractor in selecting his material for his temporary staging, centring, and details of a similar description.

An expedient was proposed with regard to centres at the time the agitation was strong respecting the Britannia Bridge, which displayed considerable skill and ingenuity. The principle is applicable in all cases when a bridge is to be erected over a river or portion of the sea, and in which the character of the situation forbids the construction *in situ* of any temporary supports. Let us suppose that the example is that of an arch of iron. The centre is first put up on a pontoon, and the arch built up over it, and secured in a perfectly firm and reliable manner. The pontoon is then floated to the site, and adjusted so that, by the falling of the tide, or by other mechanical means, the arch should rest on its bearings. The further sinking of the pontoon, carrying the centre with it, leaves the arch to itself, and, in a short time, the whole is floated away, and the waterway restored to its previous unimpeded condition. In designing a centre the chief objects to be kept in view are the employment of as few parts as possible, and the insuring that each component member does its proper share of duty. If timber be the material used, the connections should be all strongly made, and at the same time as few holes made in the wood as the nature of the design will permit of. This precaution is necessary for two reasons. In the first place, every bolt hole weakens the timber, and in the second, some regard must be had to the possibility of making use of it on a future occasion. Although, in one sense, it is no business of an engineer to design centres and scaffolding, otherwise than in a scientific manner, yet economy should always find a prominent place in his professional works. At the present day, estimates are scrutinized so exceedingly closely that it behooves every engineer to have a wholesome regard for economy in all details. Had space permitted, we should have drawn the atten-

tion of our readers to the methods adopted for striking and easing centring when used for the support of arches. This operation is accomplished gradually, or rather by successive small descents of the centres, until the permanent structure has taken a firm position upon its bearings. A great mistake, and one not unfrequently committed, is to strike the centres too speedily and too rapidly. Fatal accidents have happened when this error was indulged in; especially when the arches have been constructed of masonry or brick-work.

EXPERIMENTS ON THE OXIDATION OF IRON.*

By PROF. E. CRACE CALVERT, PH. D., F. R. S., ETC.

From "Nature."

Some two years since Sir Charles Fox inquired of me if I could give him the exact composition of iron rust, viz., the oxidation found on the surface of metallic iron. I replied that it was admitted by all chemists to be the hydrate of the sesquioxide of iron, containing a trace of ammonia; to this he answered that he had read several books on the subject, in which the statements referring to it differed, and from recent observations he had made, he doubted the correctness of the acknowledged composition of iron rust. He further stated that if he took a bar of rusted wrought iron, and put it in violent vibrations, by applying at one end the fall of a hammer, scales would be separated which did not appear to him to be the substance I had described. This conversation induced me to commence a series of experiments, which I shall now detail. I first carefully analyzed some specimens of iron rust, which were procured, as far as possible, from any source of contamination. Thus one of these samples was supplied to me by Sir Charles Fox, as taken from the outside of Conway Bridge, the other secured by myself at Llangollen, North Wales. These specimens gave the following results when submitted to analysis:

	Conway Bridge.	Llangollen.
Sesquioxide of iron	93.094	92.900
Protoxide of iron	5.810	6.177
Carbonate of iron	0.900	0.617
Silica	0.196	0.121
Ammonia	Trace	Trace
Carbonate of lime	——	0.295

These results clearly show the correctness of Sir Charles Fox's foresight, that the composition of the rust of iron is far more complicated than is stated in our text-books. Therefore the question may be asked, Is the oxidation of iron due to the direct action of the oxygen of the atmosphere, or to the decomposition of its aqueous vapor; or does the very small quantity of carbonic acid which it contains determine or intensify the oxidation of metallic iron? To reply to it, I have made a long series of experiments, extending over two years, and which I hope will throw some light on this very important question. Perfectly cleaned blades of steel and iron, having a gutta-percha mass at one end, were introduced in tubes which were placed over a mercury trough, and by a current of pure oxygen conducted to the top of the experimental tube; the atmosphere was displaced, and it was then easy to introduce into these tubes traces of moisture, carbonic acid, and ammonia. After a period of four months, the blades of iron so exposed gave the following results:

Dry Oxygen	No Oxidation.
Damp "	In 3 experiments, only 1 blade slightly oxidized.
Dry Carbonic Acid	No oxidation.
Damp " "	Slight appearance of a white precipitate of the iron, found to be carbonate of iron. Two only out of 6 experiments did not give these results.
Dry carbonic acid and oxygen	No oxidation.
Damp oxygen and carbonic acid	Oxidation most rapid, a few hours being sufficient. The blade assumed a dark green color which then turned brown ochre.
Dry oxygen and ammonia	No oxidation.
Damp " "	No oxidation.

* From a paper read before the Literary and Philosophical Society, London.

The above results prove that under the conditions described, pure and dry oxygen does not determine the oxidation of iron ; that moist oxygen has only feeble action ; dry or moist pure carbonic acid has no action, but that moist oxygen containing traces of carbonic acid acts most rapidly on iron, giving rise to protoxide of iron, then to carbonate of the same oxide, and lastly to a mixture of saline oxide and hydrate of the sesquioxide of iron. These facts tend to show that carbonic acid is the agent which determines the oxidation of iron, and justify me in assuming that it is the presence of carbonic acid in the atmosphere, and not its oxygen or its aqueous vapor, which determines the oxidation of iron in common air. Although this statement may be objected to at first sight, on the ground of the small amount of carbonic acid gas existing in the atmosphere, still we must bear in mind that a piece of iron, when exposed to asmospheric influences, comes in contact with large quantities of carbonic acid during 24 hours. These results appeared to me so interesting that I decided to institute several series of experiments. When perfectly clean blades of the best quality of commercial iron are placed in ordinary Manchester water, they rust with great facility, but if the water is previously well boiled and deprived of oxygen and carbonic acid, they will not rust for several weeks. Again, if a blade of the same metal is half immersed in a bottle containing equal volumes of pure distilled water and oxygen, that portion dipping in the water becomes rapidly covered with the hydrate of the peroxide of iron, whilst the upper part of the blade remains for weeks unoxidized ; but if a blade be placed in a mixture of carbonic acid and oxygen, a very different chemical action ensues, as not only that portion of the blade dipping in the water is rapidly attacked, but the upper part of it immediately shows the result of chemical action, and also the subsequent chemical reactions are greatly modified by the presence of the carbonic acid. For in this case that portion of the blade is only covered with a film of carbon, together with a dark deposit composed of carbonate of the protoxide and hydrate of the sesquioxide. The fluid, instead of remaining clear, becomes turbid. These series of experiments substantiate the interesting fact observed—that carbonic acid *promotes* oxidation. A long series of experiments were also made to try and throw some light on the curious fact, first published by Berzelius, subsequently studied by other chemists, and well known to soap and alkali manufacturers, namely, that caustic alkalies prevent the oxidation of iron ; my researches can be resumed as follows : (1) that the carbonates and bicarbonates of the alkalies possess the same property as their hydrates ; and (2) that if an iron blade is half immersed in a solution of the above-mentioned carbonates, they exert such a preservative influence on that portion of the bar which is exposed to an atmosphere of common air (oxygen and carbonic acid), that it does not oxidize even after a period of two years. Similar results were obtained with sea water, to which had been added carbonates of potash and soda.

A SINGULAR accident occurred lately upon the West Hartlepool and Stockton branch of the North-Eastern Railway. The accident occurred to the passenger train leaving Ferryhill Junction at 6.5 P.M. for Stockton and West Hartlepool. After the division of the carriages at Norton Junction for these places, the Stockton portion pursued its journey southward ; but when it arrived within a mile of its destination, the connecting-rod on the near side of the engine, suddenly snapping, was driven completely through the side of the boiler, so rending it as to allow the whole of the boiling water and steam to escape with a loud noise. The passengers were greatly alarmed, but no one was hurt.

THE returns of the quantities of gold obtained during 1870, in the gold fields of Nova Scotia, show an increased production of nearly 2,000 oz. The Albion mine produced 2,582 oz., and the Wellington mine 2,033 oz. The average yield of the colony is about 2 oz. of gold to the ton of ore ; but McAlister mine is said to have yielded ore containing 71 oz. to the ton—the highest yield which has yet been obtained. In 1869 the quantity of gold produced was 17,868 oz.

REPORT ON THE ALLEN ENGINE.

From "The Engineering and Mining Journal."

We make the following extracts from the report of Wellington Lee, C. E., on the experiments conducted last November, for the purpose of ascertaining the economy and effective power of the Allen Engine, shown at the Exhibition of the American Institute.

It was determined to conduct two separate experiments; the first, for the purpose of ascertaining the consumption of coal per hour required for each 1-horse power of work done by the steam in the cylinder, as shown by the indicator diagrams; and the second, to ascertain the percentage of its indicated power that the engine was able to give off in useful effect.

The first of these experiments was conducted on the 3d of November, the engine driving the machinery of the Exhibition, increased, as far as possible, by the addition of two pumps and two large blowers. The next day the belt was removed, and the friction-brake was adjusted to the band-wheel of the engine for the second trial. It was not got in readiness for use, however, until the afternoon of the 5th, the closing day of the Fair, and was then found to be imperfect, and the hurried experiment that was tried showed only the necessity of a greater degree of care and thoroughness in the preparation than was then possible. After the close of the Exhibition, therefore, this trial was repeated, on the 18th and 19th days of November, under my personal supervision, in as public a manner as possible, and in the presence also of two of your number, and of four of the Managers of the Institute, and it was of a character calculated to inspire entire confidence in its results.

The two trials are described, and their results given separately.

DIMENSIONS AND PARTICULARS OF THE ENGINE.

Diameter of cylinder	16 in
Length of stroke	30 "
Revolutions per minute	125
Mean piston speed in ft. per min.	625
Foot lbs. of work done per min. in the cylinder, for each 1 lb. of mean pressure	125,662.5
Horse powers exerted in the cylinder, for each pound of mean pressure	3.808
Waste room in clearance and passages (cubic in)	248
Proportion added thereby to the piston displacement	.0411
Length added thereby to the stroke (in ins.)	1.23
Diameter of fly-wheel, in feet	9.
Weight of fly-wheel (pounds)	7,800

The engine has four valves, one for admission, and one for release at each end of the cylinder.

All the valves are driven from a link worked by one eccentric.

Total throw of eccentric, $2\frac{1}{2}$ in.

The admission valves are driven from the movable block, adjusted by the action of the governor.

The cut-off is variable, by this automatic action, from the commencement up to the half-stroke.

The exhaust valves are driven from a fixed point at the extremity of the link.

The valves are equilibrium slide valves.

Each admission valve opens four passages into one port. Aggregate length of four openings, 36 in. Width of each opening, when the steam is cut off at one-fourth of the stroke, $\frac{1}{4}$ of an in.; when cut off at half stroke, $\frac{5}{8}$ of an in.

Area of admission port, $9 \times 1\frac{1}{2}$ in. $= 13\frac{1}{2}$ sq. in.

Diameter of steam pipe 6 in.

Each exhaust valve opens two passages.

Area of exhaust port and passages, 20 sq. in.

Diameter of exhaust pipe, first length and elbow, 7 in.; remainder, 8 in.

The steam was released at 27.5 in. of the stroke, and compression began at 28 in. of the return stroke.

The cylinder was not steam jacketed, except on one side by the valve chest. On the exhaust side, a belt was interposed to protect it externally from the colder exhaust current. The cylinder was covered with boiler cement cased in wood lagging, except the steam chest, which was polished. The heads were double and polished. The engine was supplied with steam from the Allen boiler, which, by carrying the water at the middle of the horizontal pipes, superheated the steam in a slight degree.

The steam pipe was well covered with boiler cement.

FIRST TRIAL.

Following the precedent of last year, the water test only was used, and the consumption of coal is calculated, on the assumption that 1 lb. of coal burned evaporated 9 lbs. of water.*

The boiler was supplied from the tank which had been used for the boiler experiments, and which had a capacity of 25 cubic ft. It was filled by a 4-in. hose from the fire-plug on the avenue.

The time occupied in filling the tank was less than a minute, and during this operation the outlet to feed the pump was closed.

The volume of steam accounted for by the indicator has been ascertained as follows: the capacity of the cylinder at the instant of release was found by adding to the stroke (30 in.), the waste-room (1.23 in.), and subtracting the distance from the termination at which the exhaust port was opened (2.5 in.), giving a length of 28.73 in. The engine was credited for each stroke with this volume of steam at the terminal pressure (14.445 lbs.). It was then charged with the steam confined at the closing of the exhaust, which filled a length of (2 + 1.23) 3.23 in., at a density of 15.8 lbs.

The calculation made on this basis gives a consumption per hour of 43,963 cubic feet of steam at the pressure of 14.345 lbs. This volume, multiplied by the decimal .0358, the weight, in decimals of a pound, of 1 cubic ft. of steam at that pressure, gives 1,573.87 lbs. of water accounted for per hour, or 92.36 per cent. of the water evaporated.

It was made impossible for any water to enter the boiler, except that drawn from the tank, and all the steam generated, except that taken by the feed pump as hereafter mentioned, was worked through the engine.

The engine was run continuously for 11 hours, from 11 A. M. to 10 P. M., with two interruptions.

The first was at 2.30 P. M., for putting on a belt, and lasted only 2 min.; the second was at 6 o'clock, to permit an exhibitor to make some connections, and was protracted to 20 min. It was not expected, however, to be more than momentary, and we were hoping every minute to start again. The boiler was not thought of until it was heard blowing off with a pressure in the pipe of over 100 lbs., making it necessary to open also the $\frac{2}{3}$-in drain pipe from the main steam pipe. The exhibitors claimed that the loss of steam was certainly quite as much as the engine would have used if running, and as I found that the tank then emptying lasted a shorter time by 3 min. than the next one did, I have thought it right to allow the claim. No account of stoppages is, therefore, made.

No counter was employed, but the engine was timed occasionally, and was always at its full speed of 125 revolutions; if inexact at all, it was in excess of this speed.

A barometer was not used, the pressure of the atmosphere is assumed at 30.154 in. of mercury, or 14.8 lbs. on the sq. in.

The boiler had been supplied by a steam pump. For this trial, arrangements were made to feed it by a pump driven from the shaft, so that all the water sent into the boiler would be werked through the engine, as it was on trials last year. Unluckily, this pump gave out entirely on the morning of the trial, and the steam had to be used all day. No allowance is attempted to be made for this waste, but it seems proper to mention the fact that the engine worked under this slight disadvantage.

An important feature of this trial was the employment of steam slightly superheated. The mean temperature of the steam in the chest was 24.14° greater than that due to the pressure, and this chamber, extending the entire length of the cylinder, and around more than $\frac{1}{4}$th of its circumference, acted also as a steam jacket, and one in which no condensation could take place.

It is interesting and highly instructive to note, in the tables, how, as the degree of superheating was raised, and at the same time a greater weight of steam was admitted to the cylinder, the percentage of the water accounted for by the indicator increased, and the economy, shown by the time required to empty the tank, was improven.

SECOND TRIAL.

For the purpose of this trial, a friction brake was fitted to the band wheel of the engine, which was very suitable for this

* The evaporative duty of the boiler was in reality greater than this.

use, being 9 ft. in diameter by 26 in. width of face.

Each 1 lb. sustained at the brake represented 4,107 ft. lbs. of work done per min. Each 8.035 lbs. sustained required the exertion of 1 horse-power.

Each 30.6 lbs. sustained counterbalanced 1 lb. of mean pressure in the cylinder.

For the purpose of making the experiments more satisfactory, and of a character to expose their own errors or verify their own accuracy, five different weights were lifted, of 143 lbs., 374 lbs., 600 lbs., 800.5 lbs., and 10315 lbs., respectively. The first consisted of that portion of the weight of the apparatus itself, which preponderated on the rising side, and which was carefully ascertained.

A number of diagrams were taken on each of the five trials, and the pencil was allowed to pass over each diagram from 20 to 30 times. The trials on the 18th were only partial, and must be regarded as preliminary.

The diagrams were taken equally from each end of the cylinder, except the seventh one on the fifth trial. Those from the opposite ends were nearly, but not precisely, equal, which accounts for the more extreme differences appearing in the tables.

On each trial the diagrams from the same end ran nearly identical, although the relation between the pressures exerted on the opposite sides of the piston varied somewhat at different points of cut-off.

The diagrams do not show an equal proportional loss from friction, but are given as they are. By comparing the diagrams on the first and fifth trials, the increase of friction caused by the load is seen to be 3.5 per cent. That is, the difference between the diagrams exceeds, by this percentage, the difference between the weights sustained.

At the conclusion of the trial, the band was removed from the wheel, and the engine was run for the purpose of obtaining the fractional diagrams, with the result given in the tables.

Steam was supplied on this trial, as on the first one, by the Allen boiler, having 900 sq. ft. of heating surface, of which 730 ft. were below the water line, and 170 ft. above it. Steam was easily kept up while the engine was exerting 141.68 horse-powers.

To test the power of the engine, the steam-pressure was run down below 60 lbs., and diagrams were taken, with an initial pressure of from 53 to 56 lbs., cutting off at .45 of the stroke, and developing 141.68 indicated horse-powers. The pressure was then raised to 90 lbs., and diagrams were taken with an initial pressure of 85 lbs., cutting off at .23 of the stroke, and developing the same power.

The following tables are those given in the report, except that we have been compelled in some instances to reduce them to a mere statement of the average results obtained.

TABLE 1.

The Water Evaporated.

The water tank was emptied twelve times.

Time required to empty the Tank.	Weight of Water furnished to Tank.	Weight of Water which the diagrams account for.	Percentage of the Water accounted for.
11 hrs.	18,750 lbs.	17,304.7 lbs.	92.29

The twelfth tank was emptied a few minutes before 10 o'clock, but the water was then too high in the boiler, and when —at 10 o'clock—the engine was stopped, it had been reduced to the precise mark at which it stood at the start. About one-seventh of the water accounted for by the indicator during the last 65 minutes was derived from preceding tanks.

TABLE No. 2.

Capacity of Tank, in cubic feet.	25
Weight of one cubic foot of water (lbs.)	62.5
Pounds of water evaporated	18,750
Pounds of water evaporated per hour	1,704 5
Pounds of coal burned per hour	189.4
Mean pressure in the cylinder, above that required to neutralize the counter pressure (lbs. on the square inch)	17.345
Horse powers exerted for each 1 lb. of mean pressure	3.808
Effective indicated power (horse power)	66.05
Coal burned per hour for each effective indicated horse power (lbs.)	2.868
Pressure of the atmosphere in lbs. on the square inch (assumed)	14.8
Mean back pressure above that of the atmosphere in lbs. on the square inch	.983
Total mean pressure in cylinder, in lbs. on the square inch	33.128
Total work done by steam in cylinder (horse powers)	126.15
Coal burned per hour for each gross horse power (lbs.)	1.5
Proportion of work done by the steam that is reckoned as effective	.5236

TABLE No. 3

To Show the Cost of the Indicated Horse Power of the Engine.

	Pressure in the Steam Pipe by Gauge.	Temperature of Steam in Chest.	Degrees of Superheat.	Initial pressure.	Proportion of Stroke at which the Steam was cut off.	Mean pressuree.	Terminal pressure.	Theoretical Terminal Pressure.	Excess of Ter. Pres. above Theoretical.	Average Back Pres. above atmosphere. (Indep't of Cushion.)
	lbs.	deg.	deg.	lbs.		lbs	lbs.	lbs.	lbs.	lbs.
A	72.975	343.9	24.14	69.965	.11	17.345	—.455	—2.085	1.63	.983
B	73.25	344	23.88	71.1	.1	16.33	—0.51	—2 57	2.06	1.03

The figures given in the upper line (A) are from diagrams taken from the forward end of the cylinder, and those in the lower line (B) from the back end.

TABLE (4) A.

Work Done at the Brake.

	1st Trial.	2d Trial.	3d Trial.	4th Trial.	5th Trial.
Weight sustained	143 lbs.	374 lbs.	605 lbs.	800.5 lbs.	1031.5 lbs.
Foot pounds of Work done per Minute	587,301	1,536,618	2,484,735	3,287,653	4,236,370
Horse Powers developed	17.797	46.546	75.295	99.624	128,375
Lbs. of Mean Pressure in Cylinder required to be in Equilibrium	4.673	12.222	19.771	26.16	33.71

TABLE (4) B.

Power Exerted in the Cylinder.

	Pounds of Mean Pressure.				
General Average	7.14	14.76	21.97	28.55	37.207
Horse Powers exerted	27.19	56 2	83.66	108.72	141 68
Percentage of useful effect	65.45	82.8	99.	91 62	90.6

	Forward End of Cylinder.		Back End of Cylinder.		
Frictional Diagrams	No. 1.	No. 2.	No. 3.	No. 4.	Average
Mean Pressure	2.225 lbs.	2.2 lbs.	2.175 lbs.	2 1 lbs.	2.175 lbs.

The Mean Back Pressure above the Atmosphere Averaged .5 lb.

TABLE 5.

Comparison of the Results with those Obtained Last Year.

	Allen.	Corliss.	Babcock & Wilcox.
Diameter of cylinder (inches)	16.	16.13	16.
Area of cylinder (square inches)	201.06	204.25	201.06
Length of stroke (inches)	30.	42.	42.
Waste room adds to stroke (inches)	1 23	1.3	.63
Revolutions per minute	125.	60.344	60.273
Feet travelled by piston per minute	625.	422.4	421.9
Cubic feet displaced by piston per hour	52,344.	37,014.	35,900.
Pressure of steam in pipes (lbs.)	72.975	80.51	81.69
Initial pressure in cylinder (lbs.)	69.965	70.943	76 148
Proportion of stroke at which steam is cut off	.11	.226	.189
Effective mean pressure (lbs.)	17.345	29 728	31.057
Effective horse powers exerted	66.05	76.579	78.792
Counter pressure above atmosphere (lbs.), see note 2	.5	.68	.8
Pressure of the atmosphere (lbs.)	14.8 (a'ssd)	14.8	15.043
Total mean pressure (lbs.)	33 128	45 208	46.9
Gross horse powers exerted	126.15	116.456	118.985
Proportion of total work done by steam in cylinder, that is reckoned as effective	.5236	.6622	.6575
Pressure at termination of stroke, relatively to that of the atmosphere (lbs.)	—.455	+5.178	+3.055
Total pressure at termination of stroke (lbs.)	14.345	20.	18.1
Weight of one cubic foot of saturated steam at the terminal pressure (lbs.)	.0358	.0487	.0447
Pounds of water evaporated per hour	1,704.5	1,995.547	2,007 746
Pounds of steam per hour, *by indicator*	1,573 87	1,815 723	1,595.496
Percentage of water accounted for by the indicator	92.36	90.99	79.47
Number of times the volume of steam is multiplied by expansion	6.3	4.3	5.
Ratio of gain by expansion	2.3	2.25	2.6
Pounds of coal per hour for each effective horse power	2.868	2.89	2.831
Pounds of coal per hour for each gross horse power.	1.5	1 9	1.87
Percentage of indicated power that was usefully exerted	91.11	90.23	87.2

From the foregoing tables it will be noticed :

I. The theoretical terminal pressure was ascertained by calculation from a point on the expansion curve after it was certain that the steam had been cut off—a method that insures accuracy.

II. During the friction brake experiments, when the steam was discharged under some pressure, the back pressure was observed to be much less than during the trials for economy. This was doubtless owing to the fact that in the former case the large body of steam in the exhaust pipe was put in motion at high velocity by the pressure at the instant of release, while in the latter it was inert, and so resisted the motion of the piston.

The difference was very marked, and when the steam was released at from 3 lbs. to 6 lbs. pressure, the back pressure could not be judged to exceed .5 of a pound. In comparing the results with those of last year, when the steam was released at about this pressure, the latter decimal must therefore be used.

III. The Allen Engine Works had requested that the engine should be loaded for the trial to the extent of at least 100 horse-powers, in order that the mean effective pressure in the cylinder should be as great, or nearly so, as it was in the engines tried last year. Efforts were made to provide this amount of resistance, but with very poor success. The diagrams show only 66.02 horse-powers exerted, requiring a mean effective pressure of only 17.345 lbs. against 29.728 in the Corliss, and 31.057 lbs. in the Babcock and Wilcox engines. No just comparison for economy can, therefore, be made, except by measuring the total work done by the steam in the cylinder in each case ; for, if the work done in overcoming the atmospheric resistance

were deducted alike in all the engines, then we would have only 52.36 per cent. of the total work done allowed to the Allen engine, and an average of 66 per cent. allowed to its competitors, as effective power, while in truth the work of the steam in overcoming the pressure of the atmosphere is precisely the same as if the resistance overcome was that of a pump or a saw-mill. To illustrate this by a more extreme case, let the mean effective pressure be only 5 lbs., making, with the atmosphere, a total pressure of 20 lbs., and let the coal burned be, as in this case, 1.5 lbs. per hour for each gross horse-power. Now, if the atmosphere is deducted, the consumption for each effective horse-power will be 6 lbs. per hour.

It is obvious that when the pressure differs so widely as in the present case, a comparison made after deducting the atmosphere would give a very enormous result.

The coal burned for the Allen engine, divided by 52.36 per cent. of the power exerted by the steam, gives a quotient that is just the mean of those obtained by dividing the coal burned for the Corliss and the Babcock & Wilcox engines by 66 per cent. of the power exerted in them ; and the coal burned in each case, divided by the total power exerted, shows a consumption for the Allen engine of 1.5 lbs. for horse power per hour, against a consumption of 1.87 lbs. for the Babcock & Wilcox engine, and of 1.9 lbs. for the Corliss engine.

This economy is believed to be without precedent, except in cases where steam has been expanded in two or more cylinders, and re-heated on the passage.

IV. The ratio of gain by expansion is ascertained by dividing the mean pressure through the stroke, which represents the work done, by the pressure at the termination of the stroke, which represents the steam consumed in doing it.

The gain of 2.3 by expansion shown in the Allen engine is perfectly correct, and consistent with the theoretical tables, as will appear, because, first, these tables make no account of waste room, and second, the terminal pressure or divisor is, on the diagrams, higher than the theoretical expansion calls for. In order to find both the point of cut-off and the mean pressure for any comparison of the diagram with the requirements of theory, the waste room must be regarded as forming a part of the piston displacement. In this case the steam was expanded to 6.3 times only, instead of 9 times its original volume.

It cannot be contended that the superior economy of the Allen engine is due to its working more expansively, as its gain from expansion was not materially different from that of the other engines.

V. At each stroke of the piston, 16,651.8 foot lbs. of work were done in the cylinder, involving a loss of 21.57 units of heat, or heat sufficient to raise the temperature of 1 lb. of water 21.57°. The weight of steam which entered the cylinder was .1136 of a lb., and it contained 138.8 units of heat. Of the 21.57 units of heat lost during the stroke, 9.38 units were lost before the closing of the port, and might have been restored directly from the boiler. The remainder, 12.19 units, were converted into work during the expansion. Of this amount, 2.78 units were supplied from heat set free by the expansion, leaving 9.41 units, which, if no other source of heat existed, must have been supplied by the condensation of nearly $\frac{1}{13}$th part of the steam. But about $\frac{1}{2}$ of the cylinder walls had a temperature equal to that of the steam in the chest, or 132° greater than that of the steam when expanded to the atmospheric pressure, and this surface was sufficient, at the rapid reciprocation employed, to impart to the steam, during its expansion, a very considerable amount of heat, and in this manner, without doubt, the heat converted into work was so far restored to the steam as to cause the indicator to account for the very large percentage of the water evaporated that is shown in Table 1.

VI. In stating the power given off by the Allen engine, in comparison with that given off by the Corliss & Babcock and Wilcox engines, it is necessary to have regard to the mean pressures exerted.

The mean effective pressure exerted in the latter engines averaged about 30 lbs. on the sq. in. of piston.

During one of the experiments with the friction brake, the mean effective pressure in the Allen engine was 28.55 lbs., and during another it was 37.207 lbs. It seems fair to take the mean of these

two as the comparative duty of this engine, which is thus fixed at 91.11 per cent. of the indicated power..

Finally, the performance of the Allen engine, it will be seen, exceeded that of the engines tried last year, both in its economy and in the proportion of its indicated power that was given off in useful effect, and also, what its high speed renders especially remarkable, in the proportion of the steam pressure in the pipe that was realized in the cylinder, and in the absence of back pressure. It ran also through the Fair, and on many of the days for 11 and 12 hrs. successively, without ever having a warm bearing.

The report is followed by the endorsement of the Judges, Messrs. Barnard, Sloan, and Weir, who witnessed the performances of the engine.

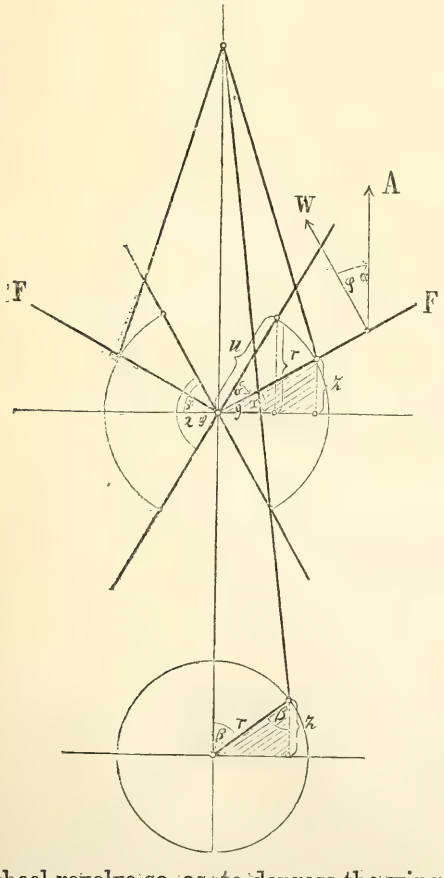
THE MECHANICS OF FLYING.

(*Continued from page* 351.)

6. DETERMINATION OF THE EQUATION OF CONDITION FOR HOVERING.

Suppose the flying apparatus has two wing-surfaces F, which can be moved by means of a wheel and axle. Let the

FIG. 5.



wheel revolve so as to depress the wings with the constant angular velocity ω_1, and to raise them with the constant angular velocity ω_2. Let the crank rod be very long, so that in calculation it may be assumed of infinite length. The force K acting at the centre of gravity is to be determined ; then its velocity can be found by integration.

$$K = A - G = W \operatorname{Cos}(-a) - G.$$

The resistance depends on the velocity of the wings. Let

ω = angular velocity of wheel in metres.
a = the momentary inclination of wing surfaces at extreme position.
β = the corresponding angle of inclination to the vertical of the handle.
ϕ = half the stroke-angle.
r = length of handle.
u = distance of connection of rod from the centre of rotation of the wing surfaces.

Then from the hatched triangles in Fig. 5, we see

$$Z = u \operatorname{Sin}(\phi - a) = r \operatorname{Cos} \beta.$$

But since

$$\frac{r}{u} = \operatorname{Sin} \phi,$$

we have

$$\operatorname{Sin}(\phi - a) = \operatorname{Sin} \phi \operatorname{Cos} \beta \quad . \quad . \quad . \quad (1.)$$

and by differentiation

$$-\frac{\operatorname{Cos}(\phi - a)\, da}{dt} = -\frac{\operatorname{Sin} \phi \operatorname{Sin} \beta\, d\beta}{dt}$$

$\frac{d\beta}{dt}$ is equal ω_1 the constant angular velocity, hence

$$\frac{da}{dt} = \omega_1 \operatorname{Sin} \phi \frac{\operatorname{Sin} \beta}{(\operatorname{Cos} \phi - a)}.$$

From (1)

$$\operatorname{Sin} \beta = \sqrt{1 - \frac{\operatorname{Sin}^2(\phi - a)}{\operatorname{Sin}^2 \phi}}$$

and this value substituted gives

$$\frac{da}{dt} = \omega_1 \frac{\sqrt{\operatorname{Sin}^2 \phi - \operatorname{Sin}^2(\phi - a)}}{\operatorname{Cos}(\phi - a)} \quad . \quad . \quad (2.)$$

The resistance of the two wing surfaces is

$$W = 2\zeta \frac{\gamma}{2g} F_1 n_1^2 \left(\frac{d a}{d t}\right)^2$$

and substituting for $\frac{d a}{d t}$,

$$W_1 = 2\zeta \frac{\gamma}{2g} F_1 n_1^2 \omega_1^2 \frac{\mathrm{Sin}^2 \phi - \mathrm{Sin}^2 (\phi - a)}{\mathrm{Cos}^2 (\phi - a)} \quad (3.)$$

and the buoyancy of both wing surfaces is

$$A_1 = W \mathrm{Cos} (\phi - a) = 2\zeta \frac{\gamma}{2g} F_1 n_1^2 \omega_1^2 \times \frac{\mathrm{Sin}^2 \phi - \mathrm{Sin}^2 (\phi - a)}{\mathrm{Cos}^2 (\phi - a)} \quad . \quad . \quad . \quad ((4.)$$

F_1 being the surface of a wing.

For the back stroke the wing surface changes to F_2. In birds it is diminished by the lapping of the feathers.

The constant angular velocity of the wheel is a_2, the radius of resistance $= n_2$, and the buoyancy is

$$A_2 = -2\zeta \frac{\gamma}{2g} F_2 n_2^2 \omega_2^2 \frac{\mathrm{Sin}^2 \phi - \mathrm{Sin}^2 (\phi - a)}{\mathrm{Cos} (\phi - a)} (5.)$$

The acceleration of the centre of gravity during the downward stroke is

$$p = g \cdot \frac{A_1 - G}{G}$$

and substituting for A_1 from (4)

$$p = g \frac{2\zeta \cdot \frac{\gamma}{2g} F_1 n_1^2 \omega_1^2 [\mathrm{Sin}^2 \phi - \mathrm{Sin}^2 (\phi - a)}{G \mathrm{Cos} (\phi - a} - g$$

But since

$$p = \frac{d v}{d t}$$

we obtain by integration between limits $t = 0$ and $t = t_1$ (down stroke).

$$v_1 - v_0 = \frac{2\zeta \cdot \frac{\gamma}{2g} \cdot F_1 n_1^2 \omega_1^2 g}{G} \int_{t=0}^{t=t_1} \frac{[\mathrm{Sin}^2 \phi - \mathrm{Sin}^2 (\phi - a)]\, d t}{\mathrm{Cos} (\phi - a)} - \int_{t=0}^{t=t_1} g\, d t$$

Substituting the value of $d t$ from (2)

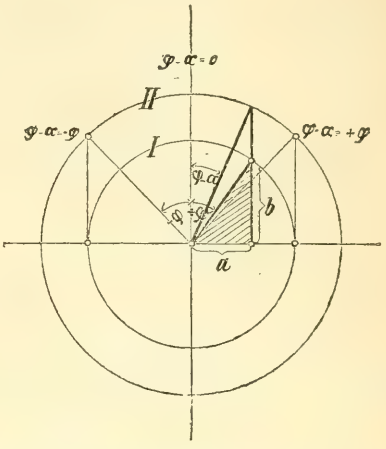
$$v_1 - v_0 = \frac{2\zeta \cdot \frac{\gamma}{2g} F_1 n_1^2 \omega_1^2 g}{G \omega_1} \int_{a=0}^{a=2\phi} \sqrt{\mathrm{Sin}^2 \phi - \mathrm{Sin}^2 (\phi - a)}\, d a - \int_{t=0}^{t=t_1} g\, d t \quad . \quad . \quad . \quad . \quad . \quad . \quad (6.)$$

DETERMINATION OF THE INTEGRAL.

$$\int_{a=0}^{a=2\phi} \sqrt{\mathrm{Sin}^2 \phi - \mathrm{Sin}^2 (\phi - a)}\, d a.$$

This integral may be found approximately by construction. In Fig. 6 the

FIG. 6.



circle I is described with radius Sin ϕ ; II, with the radius unity. In the hatched right angled triangle the hypothenuse $=$ Sin ϕ ; one side $=$ a Sin $(\phi - a)$; the other

$$b = \sqrt{\mathrm{Sin}^2 \phi - \mathrm{Sin}^2 (\varphi - a)}$$

Multiplying the ordinate of the small circle I, by the corresponding differential of the arc $d\, a$ of the large circle II, and taking the sum, we obtain the desired integral.

If Sin ϕ is small, and consequently ϕ is also small, then between the limits

$$\phi - a = -\phi \text{ and } \varphi - a = +\phi$$

$d\, a$ will differ little from $d\, x$; and as ϕ is small the value of the integral is equal to the surface of the semicircle of I.

$$\int_{a=0}^{a=2\phi} \sqrt{\mathrm{Sin}^2 \phi - \mathrm{Sin}_2 (\phi - a)} \cdot d a = 2 \frac{\pi}{4} \mathrm{Sin}^2 \phi$$

if ϕ is small.

For $\phi = \frac{\pi}{2}$ (large stroke-angle) both circles coincide ; and since from the hatched triangles we have

$$d a : d x = \mathrm{Sin} \phi : y$$

then

$$y\, d a = d x \mathrm{Sin} \phi$$

therefore constant, and the surface

$$\int_{a=0}^{a=2} \sqrt{\text{Sin}^2\,\phi - \text{Sin}^2\,(\phi-a)}\; d\,a$$

passes into the double surface of the square $\text{Sin}^2\,\phi$; therefore if ϕ is large

$$\int_{a=0}^{a=2\,\phi} \sqrt{\text{Sin}^2\,\phi - \text{Sin}^2\,(\phi-a)}\; d\,a = 2\,\text{Sin}^2\,\phi$$

While ϕ increases from 0 to $\frac{\pi}{2}$ the value of this integral varies uniformly, hence there is always a mean value.

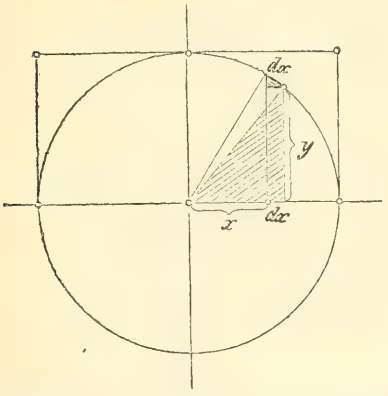
$$\frac{2\,\pi}{4}\ \text{sin}^2\,\varphi \text{ and } 2\,\text{Sin}^2\,\phi$$

and generally

$$\int_{a=0}^{a=2\ \phi} \sqrt{\text{Sin}^2\,\phi - \text{Sin}^2\,(\phi-a)}\; d\,a = 2\,\text{Sin}^2\,\phi.\Phi \quad (7.)$$

in which Φ is a function of ϕ, which always has a mean value of $\frac{\pi}{4}$ and 1.

FIG. 7.



Substituting the value of this integral in (6) gives

$$v_1 - v_0 = \frac{2\,\zeta.\frac{\gamma}{2\,g}\,\text{F}_1\,n_1^2\,\omega_1^2\,g}{\text{G}\,\omega_1} 2\,\text{Sin}_2\,\phi.\Phi - g t_1 \quad (6a.)$$

for the back stroke

$$v_2 - v_1 = -\frac{2\,\zeta.\frac{\gamma}{2\,g}\,\text{F}_2\,n_2^2\,\omega_2^2\,g}{\text{G}\,\omega_2} 2\,\text{Sin}_2\,\phi\,\Phi - g t_2 \quad (6b.)$$

$$2\,\zeta\,\frac{\gamma}{2\,g}\,\text{F}_1\,n_1^2\,\omega_1^2\,\text{Sin}^2\phi$$

is the maximum resistance of both winged surfaces (in mean position) during the down stroke. This we denote by $\text{W}_m^{\,1}$.

$$2\,\zeta\frac{\gamma}{2\,g}\,.\,\text{F}_2\,n_2^2\,\omega_2^2\,\text{Sin}^2\phi$$

is the maximum resistance of both surfaces during up-stroke, and is denoted by $\text{W}_m^{\,11}$, hence we have

$$\text{V}_1 - \text{V}_0 = \left[\frac{2\,\text{W}_m^{\,1}\,\Phi}{\text{G}\,\omega_1} - t_1\right] \text{ and } \text{V}_2 - \text{V}_1 = -g\left[\frac{2\,\text{W}_m^{\,11}\,\Phi}{\text{G}\,\omega_2} - t^2\right].$$

Instead of the angular velocity ω_1 and ω_2 the time of down-stroke and back stroke can be substituted. The path of a point in the handle at the distance 1 from the axis, during up or down stroke is π. Hence

$$\pi = t_1\,\omega_1 \text{ and } \pi = t_2\,\omega_2 \quad . \quad . \quad . \quad (8.)$$

Substituting

$$v_1 - v_0 = g\,t_1\left[\frac{2\,\text{W}_m^{\,1}\,\Phi}{\text{G}\,\pi} - 1\right] \text{ and } v_2 - v_1 = -g\,t_2\left[\frac{2\,\text{W}_m^{\,11}\,\Phi}{\text{G}\,\pi} + 1\right] \quad . \quad . \quad . \quad (9.)$$

For hovering

$$v_1 = -v_0 = -v_2$$

hence

$$g\,t_1\left[\frac{2\,\text{W}_m^{\,1}\,\Phi}{\text{G}\,\pi} - 1\right] = g\,t_2\left[\frac{2\,\text{W}_m^{\,11}\,\Phi}{\text{G}\,\pi} + 1\right]$$

from which

$$\text{W}_m^{\,1}\,t_1 = \text{W}_m^{\,11}\,t_2 = \frac{(t_1 + t_2)\,\text{G}\,\pi}{2\,\Phi}$$

Putting

$$\frac{t_2}{t_1} = k, \ \ldots\ \text{W}_m^{\,1} - \text{W}_m^{\,11}\,k = \frac{(1+k)\,\text{G}\,\pi}{2\,\Phi} \quad . \quad (10)$$

This is the condition of floating or hovering. W_2 is always small compared with W_1; neglecting this we have for large stroke angle $\phi = 1$.

If $k = 1$	$k = \frac{1}{2}$	$k = \frac{1}{3}$	$k = 0$
$\text{W}_{m_1} = \frac{1}{4}\,\text{G}$	$= \frac{3}{4}\,\pi\,\text{G}$	$= \frac{3}{8}\,\pi\,\text{F}$	$= \frac{1}{2}\,\pi\,\text{G}.$

Hence we see that the maximum resistance of the wings is great; and within practical limits may be taken as equal to twice the weight of the bird.

(7.)—DETERMINATION OF THE NUMBER OF STROKES.

The condition for hovering is equation (10.)

$$\text{W}_m^{\,1} - \text{W}_m^{\,11}\,k = \frac{(1+k)\,\text{G}\,\pi}{2\,\Phi}$$

in which

$$\text{W}_m^{\,1}\,2\,\zeta = \frac{\gamma}{2\,g}\,\text{F}_1\,n_1^2\,\omega_1\,\text{Sin}^2\,\phi =$$

$$2\,\zeta\,\frac{\gamma}{2\,g}\,\text{F}_1\,n_1^2\,\text{Sin}^2\,\phi\,\frac{\pi^2}{t_1^{\,2}}$$

and

$$W_m{}^{11} = 2\zeta \frac{\gamma}{2g} F_2 n_2{}^2 \omega_2{}^2 \operatorname{Sin}^2 \phi =$$

$$2\zeta \frac{\gamma}{2g} F^2 n_2{}^2 \operatorname{Sin} \phi \frac{\pi^2}{t_2{}^2}$$

This value substituted gives

$$2\zeta \frac{\gamma}{2g} \pi^2 \operatorname{Sin}^2 \phi \left[F_1 n_1{}^2 - \frac{F_2 n_2{}^2}{k_2} \right] = \frac{(t_1{}^2\ 1+k)\ \pi G.}{2\Phi}$$

Hence

$$t_1 = \operatorname{Sin} \phi \sqrt{\frac{2\zeta\gamma\pi\Phi (F_1 k^2 n_1{}^2) - F_2 n_2{}^2}{g\ (1+k)\ G\ k^2}} \qquad (11.)$$

and

$$t_2 = t_1 k.$$

The time of a whole period (up and down stroke) T is equal to $t_1 + t_2$, and the number of strokes per second required for hovering is

$$s = \frac{1}{T} = \frac{1}{t_1 + t_2} = \frac{1}{t_1(1+k)} = \frac{\omega_1}{\pi\ (1+k)} \qquad (12.)$$

From this it appears that s is inversely proportional to the sine of the wing-stroke. For large angles a less number of strokes is required. Neglecting W_2, we have

$$t_1 = n_1 \operatorname{Sin} \phi \sqrt{\frac{2\zeta\gamma\pi\Phi F_1}{g\ (1+k)\ G}} \qquad (11a.)$$

(8.) Determination of the Work.

The resistance is a force W, acting at a distance m from the axis; the work for a stroke is therefore.

$$A_1 = m_1 \int_{a=0}^{a=2\phi} W^1 d\,a \text{ for down stroke}$$

$$A_2 = m_2 \int_{a=0}^{a=\phi} W^{11}\, d\,a \text{ for back stroke}$$

in which W^1 and W^{11} are resistances; the value of W^1 being given in equation (3.)

The maximum resistance of $W_m{}^1$ is

$$W_m{}^1 = 2\zeta \frac{\gamma}{2g} F_1 n_1{}^2 \omega_1{}^2 \operatorname{Sin}^2 \phi,$$

hence

$$W^1 = W_m{}^1 \frac{\operatorname{Sin}^2 \phi - \operatorname{Sin}^2 (\phi - a)}{\operatorname{Sin}^2 \phi\ \operatorname{Cos}^2 (\phi - a)}$$

And the work

$$A_1 = \frac{m_1\ W_m{}^1}{\operatorname{Sin}^2 \phi} \int_{a=0}^{a=2\phi} \frac{\operatorname{Sin}^2 \phi - \operatorname{Sin}^2 (\phi - a)}{\operatorname{Cos}^2 (\varphi - a)}\, d\,a$$

This integration gives

$$A_1 = \frac{m_1\ W_m{}^4}{\operatorname{Sin}^2 \phi} \left[2\,tg\,\phi \operatorname{Sin}^2 \phi - 2\,tg\,\phi + 2\phi \right]$$

Reducing,

$$A_1 = \frac{m^1\ W_m{}^1}{\operatorname{Sin}^2 \phi} \left[\phi - \frac{1}{2} \operatorname{Sin} 2\phi \right]$$

The work for back-stroke is

$$A^2 = \frac{m^2\ W_m{}^{11}}{\operatorname{Sin}^2 \phi} \left[\phi - \frac{1}{2} \operatorname{Sin} 2\phi \right]$$

The total work is

$$A_1 + A_2 = \frac{2\ (\phi - \frac{1}{2} \operatorname{Sin} 2\phi)}{\operatorname{Sin}^2 \phi} \left[W_m{}^1 m_1 + W_m{}^{11} m_2 \right]$$

And the work per second

$$(A_1 + A_2)\, s = s. \frac{2(\phi - \frac{1}{2} \operatorname{Sin} 2\phi)}{\operatorname{Sin}^2 \phi} \left[W_m{}^1 m_1 + W_m{}^{11} m_2 \right]$$

Neglecting $W_m{}^{11}$ compared with $W_m{}^1$ and substituting from (10) the value of $W_m{}^1$, and from (12) and (11a) the value of s; we have the total work per second.

$$A = \frac{2}{\operatorname{Sin}^3 \phi\, \Phi\, \frac{3}{2}} G \frac{m_1}{n_1} \sqrt{\frac{\pi\ g\ (1+k)\ G}{2\zeta\gamma F_1}} \qquad (13.)$$

Determination of the Value of the Function.

$$\frac{\phi - \frac{1}{2} \operatorname{Sin} 2\phi}{\operatorname{Sin}^3 \phi\ \Phi\ \frac{3}{2}} = f$$

For

$$\phi = \frac{\pi}{2}, f = \frac{\pi}{2} = 1.57, \text{ hence } \Phi = 1 \text{ if } \phi\ \frac{\pi}{2}.$$

For

$$\phi = 0, f = \frac{0}{0}.$$

The quotient for differentials of numerator and denominator is

$$\frac{1 - \operatorname{Cos} 2\phi}{3 \operatorname{Sin}^2 \phi \operatorname{Cos} \phi\ \Phi\ \frac{3}{2}} = \frac{0}{0}, \text{ if } \phi = 0.$$

Differentiating again,

$$\frac{2 \operatorname{Sin} 2\phi}{3\ (2 \operatorname{Cos}^2 \phi \operatorname{Sin} \phi - \operatorname{Sin}^3 \phi)\ \Phi\ \frac{3}{2}}$$

Reducing

$$\frac{4 \operatorname{Sin} \phi \operatorname{Cos} \phi}{3 \operatorname{Sin} \phi\ (2 \operatorname{Cos}^2 \phi - \operatorname{Sin}^2 \phi)\ \Phi\ \frac{3}{2}} = \frac{4 \operatorname{Cos} \phi}{(6 \operatorname{Cos}^2 \phi - 3 \operatorname{Sin}^2 \phi) \Phi\ \frac{3}{2}}$$

For

$$\phi = 0, f = \frac{4}{6\ \Phi\ \frac{3}{2}} = \frac{2}{3\ \Phi\ \frac{3}{2}}.$$

For

$$\phi = 0,\ \Phi = \frac{\pi}{4}$$

hence

$$f = \frac{2}{2\left(\frac{\pi}{4}\right)^{\frac{3}{2}}} = 0.96.$$

Comparing the values 0.96 and 1.57, we find that the work per second required for a bird to maintain a hovering condition, is generally smaller for small stroke-angles. But equation (11) shows that in this case the number of strokes is very great, and therefore demands a greater expenditure of work in moving the wings outward and inward.

As the following calculation is intended to be approximate, a constant value may be taken for f. The mean of 1.56 and 0.96 is 1.26.

The value $\frac{m}{n}$ varies with the form of the wing.

For rectangular form,

$$m = \frac{3}{4}a;\ n = 0.577\ a \text{ and } \frac{m}{n} = 1.29.$$

For parabolic form,

$$m = \frac{2}{3}l;\ n = 0.479\ l \text{ and } \frac{m}{n} = 1.39.$$

The form of the wing, therefore, has little influence.

Under these special conditions the work, expressed in metre-kilograms, is

$$A = 2.20\ G \sqrt{\frac{G}{F_1}(1+k)} \quad . \quad . \quad (13a.)$$

in which G (the weight of the bird) is in kilograms, F_1 (the surface of the wing) is in square meters.

The number of wing-strokes per second for large angles, by (11a) and (12) is

$$s = \frac{0.78}{l}\sqrt{\frac{G}{F_1(l+k)}} \quad . \quad . \quad (12a.)$$

l being the wing-length in metres. Hence it appears that the greater the wing-surface, the smaller the work required, and the less the number of wing-strokes.

We will consider the three cases in which

$$k = \frac{t_1}{t_2} = \frac{1}{\infty} = 0;\ \frac{t_1}{t_2} = \frac{1}{3};\ \text{and } \frac{t_1}{t_2} = \frac{1}{2}$$

The following table gives for certain birds the weight, length of wing, wing-surface, and the calculated value of s and A.

Name.	Weight in Kilog.	Length of Wing. Metres.	Breadth.	Wing Surface. Square Metre.	Number of Strokes per Second, in Hovering. S.			Work per Second referred to Weight A.			In Kilo-grams. A
	G.	l	b	F	$k=0$	$k=\frac{1}{8}$	$k=\frac{1}{4}$	$k=0$	$k=\frac{1}{8}$	$k=\frac{1}{4}$	$k=0$
Eagle...	3.37	0.92	0.37	0.230	3.2	2.8	2.6	8.43 G	9.77 G	10.4 G	28.4
Crow...	0.52	0.46	0 20	0.061	4.9	4.3	4.0	6.38 G	7 40 G	7.85 G	3.32
Dove....	0.34	0.30	0.13	0 026	9 3	8.1	7 6	7.92 G	9 18 G	9.74 G	2.69
Sparrow	0.03	0.12	0 06	0.0048	15 9	13.7	12.9	5.39 G	6.25 G	6.63 G	0 16

From which it is seen that the work which a bird must do in flight is great in proportion to its weight. A man with the greatest exertion, as in running up stairs, raises his own weight not more than a metre in a second, while the work necessary for flight is at least five times as great. So man will never be able to raise himself on wings by means of his own muscular exertion. The small values which Prechtl obtained are due to the erroneous assumption that the whole work done by a bird is expended in raising its own weight.

From the above tables it appears that an apparatus in which the ratio of wing-surface and total weight is the same as in the case of the eagle, should not weigh more than 8.9 kilograms per horse-power. Considering that still more force is required for progression, that a good non-condensing engine requires 20 kilog. of water and coal per hour, that the proper weight of this machine is five times this value, and that to all this must be added the weight of the wing-apparatus, there seems to be little hope that flying machines can be driven by our present steam motors.

The Admiralty have decided not to incur any expense in making preliminary experiments to test Captain Moncrieff's plan for working ships' guns by means of hydraulic pressure.

ON SKEW BRIDES, AND ON THE CONSTRUCTION OF FALLS BRIDGE OVER THE SCHUYLKILL.*

Falls Bridge, over the River Schuylkill, on the Philadelphia and Reading Railroad, is a stone structure with six arches of eighty-three feet span and twenty-four feet raise. Each arch consists of eight square-built ribs of three by three feet in section, and each rib sits eighteen inches back of its fellow, making a skew of twelve feet in a width of twenty-four.

Before entering upon a description of this structure and the mode of building it, it is due to the memory of one of the brightest ornaments of our profession (B. H. Latrobe, the elder), that I should refer briefly to the origin and history of ribbed arches, which, from the materials furnished me by B. H. Latrobe, the younger, I may be enabled to do with some little emphasis.

The sketch which I now submit to the Society is a design by Mr. Latrobe, in 1808, for a brick bridge over Rock Run, in Washington, D. C., with an arch of one hundred and fifty feet span and twenty-five feet raise; it will be observed that the arch consists of four ribs of three and six feet in width, connected with transverse arches of eight and ten feet spans, and, from a note upon it, that it is a copy of a bridge previously built by the same engineer over the Medway, in England, and that he had applied for a patent. He also built a brick bridge over the canal in the District of Columbia, about the same time, which is yet standing as he left it more than fifty years ago; it is a ribbed arch of about sixty feet span, and is considerably skewed. I also submit a design of his for a bridge with ribbed brick arches over the River Schuylkill, at Philadelphia, with two spans of two hundred feet, and one of two hundred and fifty feet, which was made in 1802, but which was not executed.

We next find the system renewed in England for carrying wagon roads over the London and Croydon Railway; I quote from Weale's description of one of these structures printed in 1843 :

"This is an oblique bridge built on entirely novel principles, from the design and under the direction of Joseph Gibbs, Esq., Engineer of the Croydon Railway. The whole bridge is of brick work, and instead of the arch being built in spiral courses as in the common skew bridge, it is composed of four ribs or square arches three feet in width, and the direction of the courses, in all these ribs, is at right angles to the roadway over the bridge. It is evident that a bridge may be built on this principle at any angle, however acute, and all the expense and trouble of skew arches avoided. The bridges of this kind on the Croydon Railway are universally admired for their elegance and simplicity." But Mr. Gibbs had been antedated more than a quarter of century by Mr. Latrobe both in England and America; and it is not more remarkable that this simple mode of building oblique arches should have been so long hidden from the architectural world than that extinct races of men, who have left behind them monuments of masonry which are studied to advantage in the present enlightened age, were without the knowledge of the arch in any of its shapes.

The first ribbed arch bridge for sustaining the weight and jar of railway trains in this country, was built on the line of the Philadelphia and Reading Railroad in 1848, at a point known as "Third Crossing." It is a stone structure, with three spans of 42 ft., and a raise of 12 ft. Each arch consists of 4 square built ribs, with a backset of $1\frac{1}{4}$ ft., and a skew of 5 ft.

Circumstances made it necessary to remove the centres from this structure as soon as the arches were keyed, and for an entire winter they sustained the heavy traffic of that road unaided by backing or spandrels, and thus their sufficient stability was demonstrated in the most practical manner.

This bridge was duplicated by Mr. Edward Miller, on the Pennsylvania Railroad, about a year later, after which the system came into general use.

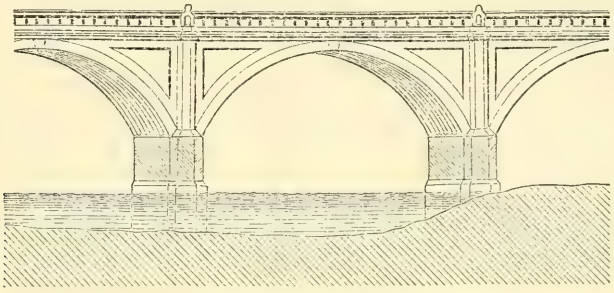
The designs for Falls Bridge were made in 1852, and the work was commenced in 1853, and finished in 1856 ; it was the most elaborate application of ribbed arches of its date. The feature in its con-

*A Paper read before the American Society of Civil Engineers, by J. Dutton Seele, Civil Engineer, Member of the Society.

struction which has attracted most attention is the fact of its occupying exactly the same site as did the wooden structure for which it is the substitute. Steamboats plied under it whilst it was building, and passengers were surprised to see the old wooden structure gradually disappearing and the new stone bridge taking its place, but the most difficult part of the work was the foundations.

The Falls of Schuylkill, which gave name to this locality, was originally a considerable rapids in the river where the waters found their hurried way among granite boulders at the head of tide. These boulders had been connected with deposits of riprap, forming wing dams to drive machinery, and at a later date both the boulders and ripraps had been submerged to a depth of 5 or 6 ft., by the construction of Fairmound dam of the Philadelphia Waterworks, and stern-wheeled steamboats plied over them. Thus it was that the rock bed of the river had become covered with masses of loose stones to a depth of 5 or 6 ft., with about an equal depth of water over them.

As coffer-dams could not be founded upon these loose materials, their sites were cleared with diving bells before they



FALLS BRIDGE.

were sunk, that the filling might rest upon the rock.

The foundations were obtained in from 12 to 15 ft. of water, and in all cases the cut stone masonry not only rested upon, but was fitted to, the rock bed of the river.

The diving bells were made of plate-iron suitably weighted and supplied with air through a hose attached to the top. The workmen remained in them 5 hours at a time, and the air was changed every 15 or 20 minutes.

Two of the piers occupy the same places as did the piers of the old structure, in which cases strong trestles were placed inside of the coffer-dam to sustain the wooden superstructure whilst the old piers were being removed and the new substituted for them.

Two seasons were occupied in obtaining the foundations and raising the piers to the springing line, and one in turning the arches and building the spandrels.

In describing the mode of turning the arches without interrupting the traffic upon the railroad above, or on the river below, it must be observed that the structure which they took the place of was a deck lattice bridge, the bottom chord of which was 5 ft. above the springing line of the stone arches. After the new piers were built, the first operation was to support this lattice superstructure upon strong trestles resting upon the centres and between the skew-backs. These trestles were not removed, and they are the only wood work built into the masonry. It will be observed thus far that we have increased the strength of the old structure by reducing its spans, and the remaining piers of the old bridge were then taken down.

The centres for turning the arches were of lattice, corresponding in plan with the trusses of the old bridge, and the trusses were made use of as a portion of the centring by bolting segments upon them. Working platforms upon which were rail tracks for moving the stone, and derricks for handling them, passed along either side of the bridge, supported upon beams which rested on the chord of the old structure about 10 ft. above the springing line.

These arrangements being completed and the arch stones being ready, the work

of turning the arches was a simple operation and did not consume a great deal of time. That portion of the old lattice trusses above the arches was cut away as the work progressed, and the rail tracks on the top were supported upon the masonry. When the arches were keyed, those portions of the old structure below them were lowered away with the centring.

The tops of the arches were covered with flat stones from 4 to 6 ft. long, which gave some bond to the ribs, enough for ordinary cases; but the constant passage of coal trains caused more vibration than was desirable, and tie rods were placed across the arches, binding the keystones on either side together for the purpose of steadying the ribs while the spandrels were being built.

Four thousand stone, each 3 ft. square, and averaging about 1 ft. thick, were required to turn the arches, and this gave occasion to note an unexpected difficulty in obtaining so large a number of sound stones of one definite size; no bond of masonry is deemed admissible between the ribs of oblique arches.

I also submit to the Society several other plans of stone bridges on the Philadelphia and Reading Railroad, which will indicate the general character of the structures; if they may be deemed of little value, they will do no harm.

The cylindrical spandrel arches have produced satisfactory results, lightening the structure over the piers and giving bond to the spandrels.

All these bridges were built in the place of wooden structures without interrupting the business of the road, and the practice gave an unusual opportunity of observing the extent to which the stability of simple stone arches without the support of spandrels or backing may be depended upon. The centres were generally removed as soon as the arches were keyed, and the backing carried up to those joints of the arches which made angles of 30 deg. with the horizon, and in no case did the arches so supported fail to sustain the heavy trains which were passing over them, without material vibration.

The plan of "Peacock's Locks Bridge" was a ribbed arch of 76 ft. span and 23 ft. raise over a canal. It was necessary to turn this arch in a severe winter, with the temperature considerably below freezing point, from the time the first stone was laid until the centres were removed, and it was interesting to observe the settling of the ribs as the frost left the mortar. They separated at one point as much as 3 in., but retained their stability perfectly, and after the cracks were filled and the spandrels built, no further derangement took place, and it would take a close observer, at this day, to discover any of the injurious results of that hard, and, as many thought, precarious winter work.

At the usual monthly meeting of the Association of Engineers, in Glasgow, Mr. Charles H. Reynolds, read a most elaborate and carefully prepared paper on "The Arrangement of the Fastenings of Iron Structures," confining himself more particularly to the functions of iron plates and rivets, individually and collectively, in malleable iron structures, subject to local straining and varying conditions of equilibrium — taking for example an iron-built ship, as being about the best instance of one structure being subject to severe alternations of repose and distress, and irregularly recurring periods of compression, tension, and shearing. He entered particularly into the plating of ships and the various modes of riveting, and quoted the results of the latest experiments on such. The paper was listened to with much interest, and a full discussion ensued.

Into one of the quietest coves of the Land's End district, immediately under the shadow of the ancient Logan Rock, is brought the cable of the Falmouth, Gibraltar, and Malta Electric Telegraph. There, in the valley of Porthcurno, is a large establishment, in which about a dozen clerks were, before the cable was broken in the winter, actively engaged in communicating with the East. The mischief is now repaired, and since the restoration of the Porthcurno cable, messages have been regularly received from India, Singapore, and Java, within three or four hours of absolute time.

The floating capital upon the Mississippi river is estimated at $1,500,000,000.

THE NATURE OF THE EARTH'S INTERIOR.

By DAVID FORBES.

From "Nature."

In a previous discourse on volcanoes, I directed attention to the phenomena of volcanic action, specially considered in relation to the part which such igneous or internal forces have played in determining the grand features of the external configuration of the sphere upon which we live.

If now we follow up this subject still further, it will naturally lead to an inquiry into the nature of the internal substance of the globe itself, within which the foci of such agencies must be situated; quite independent of this, however, I have little doubt but that many of you must at some time or other have already asked yourselves the question—What does the central mass of the earth beneath us consist of?

The answer which, in the first instance, would, I imagine, be most likely to suggest itself to your minds, would be that it consisted of solid stone, such as you see forming the body of its mountains, the foundations of its continents, and the rock basins which contain its seas. The belief in such an hypothesis would, however, be rudely shaken by the first personal experience of the shock of an earthquake, the sight of a volcano in eruption, or the consideration of the immense faults which have dislocated many parts of the solid land; since, so far from disposing us to regard the ground under us as entitled to the appellation of the terra firma, so commonly used by the ancients, the study of such phenomena could not but suggest grave doubts in our minds as to whether the earth was, after all, anything like so solid or stable as we at first sight felt inclined to imagine.

But very little inquiry into the subject is necessary, however, to convince any one of the great difficulties in the way of obtaining a satisfactory answer to this question, and to prove that at present we do not have at our command sufficient data or evidence to enable us to arrive at a thoroughly conclusive solution of this most interesting problem.

As the rapid advances made by the natural sciences are, however, daily adding to our information on this subject, and thus enabling us to correct or modify our previous deductions, so as to form a more and more trustworthy opinion on the nature of those parts of our globe, which, from their position, must always remain inaccessible to our powers of direct observation, I have imagined that a short sketch of the present state of our knowledge concerning the probable constitution of the interior of the earth might prove interesting.

In treating this subject, we will first consider what has already been done in the way of direct examination of the earth's substance in depth; yet when it is remembered that the mean diameter of our planet is some 7,912 miles, whilst the greatest depth hitherto attained by man's direct exploration has not even yet reached one mile from the surface downwards, this disproportion appears so enormous as to render it self-evident, in the pursuit of this inquiry, especially as regards the more central portions of the earth, that we must in the main rely upon data furnished by calling in the aid of the natural sciences. The direct examination of the exterior of the earth, even when restricted to this depth, does nevertheless furnish us with many important data from which to start in this to a great degree speculative inquiry, and to some of these we shall now direct attention.

It must first of all be remembered that all the rocks which we meet with at the surface, and which compose so much of the solid exterior of our globe as is actually known to us, may be arranged under two principal heads, viz., the volcanic or endogenous rocks, *i.e.* those formed within the body of the earth itself, and the sedimentary or exogenous, *i.e.* those rocks formed, or rather reconstructed, upon its surface, out of the débris of previously existing rocks arranged in beds or strata by the mechanical action of water.

It was long taken for granted by geologists that the lowest sedimentary strata, in their normal or in a more or less altered condition, rested directly upon granite, which was for a long time regarded as the foundation upon which they, in the

first instance, had been deposited, since this rock has been looked upon as the oldest of all, and as representing the primeval or original surface covering of the earth.

Later researches, however, have proved this hypothesis to be untenable, since it appears that no instance of a granite has as yet been met with in nature, which, if followed up, does not at some place or other break through, and alter or disturb, more or less, the stratified rocks in immediate contact with it ; so that it naturally follows that such stratified rocks must have preëxisted on the spot, or in other words, that they were older in geological chronology than the granite which came to disturb them.

In the present state of geology, however, it is utterly impossible for us to point out any variety of rock whatsoever as the one which may have served as a foundation upon which the oldest sedimentary rocks were originally deposited, in fact the oldest rocks which we know of at present are themselves sedimentary rocks (mostly in an altered condition) belonging to the Laurentian series in Canada, and as yet it has not been found out what these sedimentary beds may in their turn rest upon, *i.e.*, what is actually below them.

As, therefore, we have not as yet been able to reach down to investigate directly any rocks lower in the geological series than those pertaining to the Laurentian formation, we will now turn to the volcanoes, in order to examine the mineral products which they bring up for our consideration, from depths vastly beyond those which we can ever hope to reach directly. What volcanoes teach us with regard to the nature of the earth's interior, at a depth from which they derive their supply of mineral matter, may be summarized as follows :

That at this depth, the earth's substance exists in a state of perfect molten liquidity, forming as it were a sea of molten rock, analogous in character to the eruptive rocks which have broken through the earth's crust in former times. Secondly, that the mineral products ejected from volcanoes are very similar to one another in chemical and mineral constitution, no matter what part of the globe they may emanate from. And, lastly, that from the same volcanic orifice, and during the same eruption, lavas of two totally different classes may be emitted, viz., the light acid, or trachytic lava, analogous to the granites, felsites, etc., of the oldest period, and the heavy basic or pyroxenic lava, all but identical with the dark basaltic or trappean rocks, commonly met with as dykes, &c., disturbing most of the different sedimentary formations.

Another deduction from the study of volcanic phenomena, indicating that at a certain depth below their surface they must be in connection with a continuous sea of molten lava, is based upon the influence which the moon appears to have on volcanic eruptions ; this opinion seems to have been confirmed by observations of Prof. Palmieri made during the last eruption of Vesuvius, on which occasion he reported that distinct tidal phenomena could be recognized, thereby indicating that the moon's attraction occasioned tides in the central zone of molten lava, in quite a similar manner as it causes them in the ocean. A further corroboration of this view is seen in the results of an examination of the records of some 7,000 earthquake shocks, which occurred during the first half of this century, compiled by Perry, and which, according to him, demonstrate that earthquakes are much more frequent in the conjunction and opposition of the moon than at other times, more so when the moon is near the earth than when it is distant, and also more frequent in the hour of its passage through the meridian.

Returning now to the more direct examination of the superficial parts of the earth, we find that the results of mining operations have also thrown considerable light, not only on the mineral nature of the rocks encountered in depth, but also upon some of their physical conditions. A numerous set of experiments made in deep mines in various parts of the world, often far distant from one another, has most conclusively proved that the temperature of the earth, at least as deep down from the surface as has been explored by man, increases in direct ratio as we descend towards its centre. Other observations on the temperature of the water from deep-seated and hot springs, and from artesian wells, fully confirm the experiments made in mines, and show that the temperature of the water furnished by them also becomes higher in proportion

to the depth of the source from which it is derived.

As might naturally be expected, the interference of local causes renders it a matter of considerable difficulty to determine the true mean general rate of such increase in temperature of the earth's substance downwards ; still, in the main, observers all agree in placing it at somewhere between $1\frac{1}{2}$ deg. and $2\frac{1}{2}$ deg. F. for every 100 ft. in depth, so that we cannot be far wrong, if for our purpose we estimate it at 2 deg. F. for every 100 ft. in depth, or a rate which amounts to 121 deg. for each geographical mile nearer the earth's centre. Since no facts are at the present time known which can in any way invalidate the supposition that this or a somewhat similar rate of increase in temperature holds good in still greater depths, it is perfectly correct and justifiable reasoning to assume that such is actually the case, and therefore a simple calculation will show that at a depth of about 25 geographical miles from the surface downwards, a temperature of about 3,000 deg. F. should be attained, which would represent a heat at which iron melts, or one sufficient to keep lava in a state of perfect molten liquidity at the surface of the earth. As it must be remembered, however, that at this depth the substance of the earth would be exposed to the pressure of the superincumbent mass, and as it has been shown by experiment that many substances become more refractory—*i. e.*, require a greater degree of heat to melt them—when exposed to pressure than when at the surface, the above calculation will have to be modified considerably in order to meet this condition. Unfortunately, we have not as yet sufficient data at command to enable us to estimate the true ratio in which the melting points of such rocks would become elevated by pressure ; yet we may safely take it for granted, after allowing far more than the maximum rate of increase, deduced from the experiments of Bunsen and Hopkins, that we should not require to sink so deep again in order to attain a temperature fully sufficient to keep such substances in a state of fusion, or, in other words, this deduction necessitates the supposition that the solid rock crust of the earth cannot, at the utmost, be more than 50 miles in thickness.

If we now reason from the above data as premises, it will follow as a natural consequence that our globe must in reality be a sphere of molten matter, surrounded by an external shell or crust of solid matter, of very insignificant thickness when compared to the diameter of the entire globe itself ; or, in other words, this deduction represents exactly such a state of things as would ensue in the event of a sphere of molten matter becoming consolidated on its exterior by the cooling action of the external atmosphere ; and the figure of the earth itself, which is an ellipsoid of revolution, *i. e.*, a sphere somewhat flattened in at the poles, but bulging out at the equator, being that which a plastic mass revolving round its own axis would assume, is regarded by natural philosophers in general as all but conclusive evidence that the earth at an early period of its history must have been in a fluid condition.

Although the doctrine that the earth is a molten sphere, surrounded by a thin crust of solid matter, was all but universally taught by geologists, there have of late years been brought forward several arguments to the contrary, which apparently are more in favor of its being a solid or nearly solid mass throughout, and these arguments are fully entitled to our consideration, as our object is not to defend any particular theory, but to arrive as nearly as we can at the truth. I will, therefore, in the first place, proceed to scrutinize all which has been brought forward in opposition to the older hypothesis, and then to consider whether any other explanation yet advanced is more in accordance with the facts of the case.

First of all we have to answer the question as to whether it is possible for such a thin crust to remain solid, and not at once to become melted up and absorbed into the much greater mass of molten matter beneath it? This would doubtless be the case, if the central fluid mass had any means of keeping up its high temperature, independently of the amount of heat it actually possessed when it originally assumed the form of an igneous globe. This question, however, in reality answers itself in the negative, since it is evident that no crust could even commence to form on the surface, unless the sphere itself was at the moment actually giving off more heat from its outer surface to the surrounding atmosphere than it could supply from its

more central parts, in order to keep the whole in a perfectly fluid condition, so that when once such a crust, however thin, had formed upon the surface, it is self-evident that it could not again become melted up or re-absorbed into the fluid mass below.

The external process of solidification due to refrigeration would then continue going on from the outside inwards, until a thickness of crust had been attained sufficient to arrest or neutralize (owing to its bad conductibility of heat) both the cooling action of the surrounding air and the loss of more heat from the molten mass within ; and thus a stage would soon be arrived at when both these actions would so counterbalance one another that the further cooling down of the earth could be all but arrested—a condition ruling at the present time, since the earth-surface at this moment, so far from receiving any or more than a minute amount of heat from the interior, appears to depend entirely, as regards its temperature, upon the heat which it receives from the sun's rays.

We have next to consider the argument that, if the earth's exterior was in reality only such a thin covering or crust, like the shell of an egg, to which it has often been likened, such a thickness would be altogether insufficient to give to it that stability which we know it to possess, and that consequently it could never sustain the enormous weight of its mountain ranges, such as, for example, the Himalayas of Asia or the Andes of America, which are, as it were, masses of rock piled up high above its mean surface-level.

At first sight, this style of reasoning not only appears plausible, but even seems to threaten to upset the entire hypothesis altogether. It requires but little sober consideration, however, to prove that it is more, so to speak, sensational in character than actually founded on the facts of the case; for it is only requisite for us to be able to form in our minds some tangible idea of the relative proportion which the size of even the highest mountain bears to that of the entire globe itself, to convince us, if such a crust could once form and support itself, that it could with ease support the weight of the mountains also. The great Himalaya chain of mountains rises to a maximum altitude of 31,860 ft., or six miles above the level of the sea; and if the earth could be seen reduced in scale down to the size of an orange, to all intents and purposes it would look like an almost smooth ball, since even the highest mountains and the deepest valleys upon its surface would present to the eye no greater inequalities in outline than the little pimples and hollows on the outside of the skin of an ordinary orange. If this thin crust of the earth can support itself, it is not at all likely to be crushed in by the comparatively speaking insignificant weight of our greatest mountain chains, for in point of fact it would be quite as unreasonable to maintain such a position, as to declare that the shell of a hen's egg would be crushed in by simply laying a piece of a similar egg-shell upon its outside.

That a very thin spheroidal crust or shell enclosing a body of liquid matter, such as an ordinary fowl's egg, does possess in itself an enormous degree of stability and power to resist pressure from without, is easily demonstrated by merely loading a small portion of its surface with weights as long as it does not give way under them. Even when placed on its side (or least strong position) it was found that a portion of the shell only one quarter of an inch square would sustain several pounds weight without showing any symptoms of either cracking or crushing; or, in other words, this simple experiment indicates that if the external crust of the earth was but as thick and strong in proportion as an egg-shell, it would be fully capable of sustaining masses equal in volume and weight to many Himalayas piled up one atop of another, without any danger whatever to its stability.

The next argument which has been advanced against the probability of the major part of the earth's substance being in a fluid condition, is one based altogether upon astronomical considerations. It having been demonstrated when two clocks are set agoing, the pendulums of which are similar to one another in all respects, except that whilst the bob of the one is solid, that of the other is hollow and filled with mercury, that the latter will swing somewhat faster, and consequently the clock gain time upon the former. The late Mr. Hopkins, of Cambridge, applied this observation to the consideration of movements of the earth in space, and by a very elaborate course of mathe-

matical reasoning and calculation, demonstrated that the earth, if not quite solid, must be nearly so, since according to his results, if it was merely a comparatively thin shell filled with liquid matter, the ratio of certain of its movements (the precession or nutation) would differ considerably from what they are actually known to be, and these conclusions appeared to be confirmed by the subsequent calculations of Sir William Thomson and Archdeacon Pratt. Although grave doubts suggested themselves as to the correctness of the values used in these calculations for two of their most important elements, viz., the condensing action of pressure, and the expanding action of the very high temperatures within the globe —both of which have not as yet been determined with any certainty—and although it might also be surmised that the conditions of a pendulum-bob of polished glass filled with heavy slippery mercury swinging at the end of a rod, must be extremely different from those of a nearly spherical globe filled with viscid, sticky lava revolving around its own axis, still geologists felt themselves quite unable to answer the arguments of the astronomers and mathematicians; and since none of them appeared to be sufficiently versed in either astronomy or mathematics to be able to submit the method of reasoning or the calculations to any strict scrutiny, they felt themselves, reluctantly no doubt, compelled to bow to the decision of such eminent authorities.

So stood the matter until the summer of 1868, when, fortunately for the advancement of this inquiry, M. Delaunay, now Director of the Observatory at Paris, an authority equally eminent as a mathematician and an astronomer, was induced to undertake the reconsideration of this problem—a labor which has not only resulted in altogether reversing the above decision, and demonstrating the complete fallacy of the premises upon which so much elaborate reasoning had been expended, but which proved conclusively by experiment that a sphere filled with liquid matter would, under circumstances such as are present in the case of the earth, behave in precisely the same manner as an entirely solid one, and, consequently, that the fact of the earth being either solid or liquid in its interior, could neither have any influence whatever on the rate of precession or nutation, nor be of any use as a means of deciding as to the real or approximative thickness of the earth's crust.

It may also be added that the conclusions arrived at by Mr. Hopkins, even when supported by Sir William Thomson and Archdeacon Pratt, were not universally acquiesced in; the celebrated German physicist, Helmholtz, amongst others, was not satisfied as to their correctness, and in opposition to the deductions of Sir William Thomson, that the earth's crust must be some 1,000 miles in thickness, we have the entirely opposite conclusions of Mr. Henessey, whose calculations tend to show that the earth's crust cannot be less than 18 miles or more than 600 miles in thickness. We may now, however, fairly conclude that all the objections as yet advanced from an astronomical point of view against the theory of the fluid condition of the interior of our planet, have been invalidated or explained away.

The only other argument in favor of internal solidity is one which bases itself upon the law, announced upon theoretical considerations by Professor Thomson in 1849, that the fusing points of bodies must become more elevated when subjected to pressure, or, in other words, that under the influence of pressure, bodies will require more heat to melt them.

Starting from this, Bunsen argued that the earth could not be other than solid to the core, since the enormous pressure accumulated at the centre would cause its internal substance to become so infusible that it could not remain in a molten state. To a certain extent this law was corroborated by the experimental researches of Bunsen and Hopkins, made upon some of the easily fusible substances, like wax, spermaceti, paraffine, and sulphur; but as far as the later experiments went, it was not confirmed either in the case of metallic substances, nor did it appear to hold true with other than the more easily compressible bodies.

In the case of the earth, therefore, the conclusions of Bunsen cannot be accepted, since we have to deal with materials to which, as yet, this law has not been proved to apply; still, assuming, as seems most probable, that the materials composing the earth's mass do become to some extent more and more infusible according as they approach nearer to its centre, it

must, on the other hand, be remembered that this would be more or less neutralized by the expansion which these substances would undergo from the action of the internal heat ; and as incontrovertible evidence has been produced to prove that the temperature of the earth downwards from the surface increases in direct ratio with the depth, it seems most probable that the combined effects of expansion and elevated temperatures would more than counteract any tendency to solidification due to the effects of pressure.

Having now taken into consideration the various objections which have been urged against the theory of the earth's internal fluidity, as well as devoted some consideration to the opposing view of its solidity, it will be noticed, if we pass in review some of the distinctive features of the two hypotheses, that the former theory is a legitimate deduction from the data afforded by the direct study of the earth itself, whereas the latter, on the contrary, instead of making the explanation of the earth's phenomena its starting point, devotes itself almost exclusively to the task of proving that it could not be fluid.

Thus, how is it possible, if the earth's mass be solid throughout, to account for the great upheavals or sinkings down of large portions of the rock formations which compose its external crust? Do not these phenomena lead to the direct inference that the external crust cannot, by any possibility, rest in depth upon an unyielding mass of matter in the solid state, but that it must necessarily be superposed upon some more or less fluid substance, which by its mobility can, when some one portion of the crust above sinks down, become displaced, and so make room for it by elevating, or, as it were, floating up some other part of the same?

In like manner the hypothesis that the earth is essentially solid necessitated that the phenomena of volcanoes should be explained upon the supposition that they had their sources in numerous small isolated local basins of molten rock scattered over the surface of the globe ; a view which is altogether inconsistent with the results of chemical and mineralogical investigation, which proves that the ejected products are identical in constitution even if taken from volcanic vents the most distant from one another, nor does such a theory attempt to explain the tidal phenomena of volcanic outbursts and earthquakes previously alluded to.

So far, therefore, as we have gone into this subject, we may regard the balance of evidence as proving that at a depth of about 50 miles or less from the surface, there exists a continuous zone of molten rock or lava, such as is brought up to the surface by volcanic eruptions. Let us now consider how deep this zone or stratum of molten matter is likely to extend, and also what forms the more central mass of the earth below it.

In order to answer these questions we must look to other than direct evidence, and first of all must inquire whether the consideration of the mean density, or, in other words, the actual weight, of the earth itself, can throw any light upon these abstruse points. The consideration of the attraction which bodies exert upon one another in the ratio of their magnitude, has enabled the physicist to effect the at first sight apparently impracticable task of determining the entire weight of the earth itself ; but it is out of our province to describe the mode of doing so, and we must content ourselves by accepting as a fact the results of such investigations, which prove that the total weight of our planet is as near as possible $5\frac{1}{2}$ times the weight of a similar globe of pure water. Knowing now that the mean density, or specific gravity, as it is also called, of the earth is $5\frac{1}{2}$, and also, from direct experiment, that the mean density of the entire solid rock forming its external crust cannot be higher than $2\frac{1}{2}$, or less than half that of the entire sphere, it naturally follows that the central parts must be very much more heavy in order to account for so high a mean figure as $5\frac{1}{2}$, and it has been calculated that if we suppose that the earth was composed of three concentric portions of equal thickness, each in turn increasing in density towards the centre in arithmetical progression, we should then have an outer circle of specific gravity $2\frac{1}{2}$, or as heavy as rock, an intermediate zone of 12, or as heavy as quicksilver, and a central nucleus of about 20 times the density of water, or as heavy as gold.

This increase of density has sometimes been erroneously represented as entirely due to the effects of the enormous pressure of the superincumbent mass ; but this supposition is quite untenable, since

the tendency of all the numerous experiments made in this direction has been to prove that no substances can be compressed or condensed to an indefinite extent, since what may be termed their approximative maximum density is soon attained, beyond which the effects of pressure become so much smaller and smaller in proportion to the force applied, that at last the further condensation effected by still greater pressure is all but inappreciable. Besides this, it must not be forgot that the crust of the earth is a species of dome like the shell of an egg, which supports itself without resting or floating upon its fluid centre; and further that the earth's high internal heat, by causing the materials which compose it to expand, must also counteract the effects of superincumbent pressure, so that when all these facts are taken into due consideration, it appears quite evident that the materials which actually form the mass of the interior must be infinitely denser than any of the rocks met with on the surface, and that they must be metallic in their nature, since no other bodies are known which could at all fulfil these conditions of density.

If now we suppose that the earth's interior is composed of a series of concentric zones or layers made up of substances which are of more and more dense nature as they are situated nearer the centre, and that the external one is rock of a density of 2.5, a calculation will show that the centre or nucleus will be about 10, or as heavy as silver. If now we suppose that the zone of molten lava, which we have already concluded must exist at a depth of about 50 miles below the surface, has a density of 3, or say even 4, to give the fullest allowance for the condensing effects of superincumbent pressure, then we should find by calculation that this zone could not extend deeper than about 400 miles, since below this depth the matter would be so heavy that its density can only be explained on the supposition that it is made up of metallic compounds, and as the density of the still lower zones will continue to increase up to the very centre of the earth, the inference is that the whole of this great central mass situated at a distance of some 450 miles or less below the surface, is actually formed of metals and their compounds.

Whether this great central metallic nucleus is fluid or solid may next be inquired into. According to Bunsen's theory, previously alluded to, it ought to be solid, for owing to the enormous pressure to which it would be exposed, the solidification of the molten sphere should first commence at the centre. This view would be quite correct if the earth was composed of highly compressible non-metallic materials; but since this is not the case, and since, as before alluded to, the experimental data already obtained indicate that neither the metallic nor the less compressible substances become more refractory in proportion to the increase of pressure, we are more justified in assuming that the central nucleus also must be in a fluid condition, and the more so, not only because we know that metallic compounds are, as a rule, infinitely more fusible than rock silicates, but also as the well-known high temperature of the earth's interior would, by its expanding action, tend to counteract the effects of the pressure.

In summing up this inquiry, the balance of evidence appears to me to be decidedly in favor of the hypothesis that the interior of our earth is a mass of molten matter arranged in concentric layers or zones according to their respective densities, and the wole enclosed within a comparatively thin external crust or shell.

The manufacture of reaping and mowing machines has attained such large proportions as to make it one of general interest. The annual production is now estimated at about 125,000 machines. Few facts more clearly demonstrate the immense wealth of the farmers of America than that they expend each year about $20,000,000 in the purchase of implements of this one class.

Mr. F. R. Delano, Superintendent of the St. Paul & Pacific Railroad, contributes an article to the "St. Paul Press," on narrow gauge railroads, in the course of which he recommends that all the main lines across the American Continent should consist of four tracks of the 4 ft. 8½ in. gauge, two tracks for passengers and two for freight, with sidings at every 10 miles to admit of trains passing each other.

IMPROVEMENTS IN THE MANUFACTURE AND MELTING OF IRON AND STEEL.

From "The Mining Journal."

Messrs. Edwin Sunderland, manufacturer, and John F. Parker, chemist, of Birmingham, in describing their new patent, say:

Our improvements in the manufacture and melting of iron and steel, consist in the processes or modes of treatment hereinafter described.

In carrying our invention into effect, we take petroleum or other like volatile oil, and place it in an air-tight cistern, surrounded with a covering or jacket, and into the said jacket we introduce boiling water or by preference steam, or by means of a coil of piping within the cistern and under the surface of the oil, through which piping steam is passed, we raise the oil to the required temperature. We prefer a temperature of about 212 deg. Fahr. The top of the covering or jacket is provided with a self-acting valve, regulated to the desired pressure. Through an inlet-pipe we pass a current of air over the surface of the petroleum or volatile oil, which air becomes thereby carburized or charged with the vapor of the oil. By an outlet-pipe, we conduct the carburized air into a larger pipe entering the tuyere of the blast furnace or cupola employed in the manufacture or melting of the iron or steel, which larger pipe constitutes a common conduit, into which all the gases and vapors supplied to the furnace or cupola at the tuyere are passed, and by which they are conducted to the furnace or cupola. The inlet and outlet pipes are each provided with a tap.

In a retort or close chamber, exposed to heat, we place the compound called chloride of lime or bleaching powder, intimately mixed with about one-eighth its weight of dry crushed charcoal, coke, or other carbonaceous matter. This mixture evolves chlorine and carbonic oxide; or we use chloride of lime or bleaching powder alone, which, on being heated, evolves hypochlorous acid gas or a mixture of chlorine and oxygen. When we use chloride of lime or bleaching powder without carbonaceous matter, we prefer to use quicklime intimately mixed therewith in the proportion of one part by weight of quicklime to three parts by weight of chloride of lime. This admixture of quicklime with the chloride of lime facilitates the discharging of the retort and the separation of the gaseous portion of the chloride of lime from the lime. Through an inlet pipe we pass a continuous current of air over the materials in this retort or chamber, and by an outlet pipe the gaseous mixture is conducted into the larger pipe, hereinbefore referred to, which receives the carburized blast and conducts it into the tuyere of the blast furnace or cupola. The inlet and outlet pipes are provided with taps respectively.

In another retort or close chamber, exposed to heat, we place equal parts by weight of quicklime and nitrate of soda, which mixture evolves uncombined oxygen and nitrogen, nitrous acid, and nitrous oxide gases. Through an inlet pipe we pass a current of air over the materials in this retort or chamber, the gas or gases evolved being conducted by an outlet pipe into the larger pipe receiving the carburized blast, and the blast and gas or gases from the first retort or chamber, hereinbefore referred to, and which larger pump is the common conduit of the aforesaid gases and air. The inlet and outlet pipes are provided with taps respectively. The residuum or non-gaseous portion from these last-named materials being treated with boiling water, yields a solution of caustic soda mixed with lime. By subsidence these may be separated and utilized in any convenient manner.

Or, instead of driving currents of air over or through the different cisterns, retorts, or chambers, charged as described, air may be admitted through openings in them. Outlet pipes leading into the larger pipe, acting as the common conduit, conduct the air charged with the gas or vapor into the said conduit by the natural draught only of the furnace or cupola, without pressure of air by artificial means.

For the purpose of storing and equalizing the flow of the gases from the chambers or retorts described, a reservoir or holder may be interposed between each

chamber or retort, and the common conduit by which the gases and vapors are conducted to the cupola or furnace. Taps or stop-cocks, situated between the retorts and their respective reservoirs or holders, and other taps or stop-cocks between the said reservoirs or holders and the conduit, give complete control over the relative quantities of the gases or vapors admitted to the furnace or cupola.

We do not think it necessary to describe or represent the retorts and reservoirs or holders referred to, as no special construction of the same is required, retorts and holders such as are used for like purposes being suited for use in carrying our invention into effect.

The air charged with the vapor of petroleum or other like volatile oil, besides acting as gaseous fuel, also acts powerfully as a reducing agent, and rapidly effects the reduction of the iron from the ore. The air charged with chlorine or chlorine and carbonic oxide removes wholly or mainly any sulphur or phosphorus with which the ore or reduced iron may be contaminated, and the air charged with oxygen, nitrogen, and nitrous acid and nitric oxide, promotes combustion, and rapidly raises the materials to the temperature required. The air charged with vapor of petroleum may be used throughout the smelting and melting processes, and the air charged with chlorine or chlorine and carbonic oxide, as well as the air charged with oxygen, nitrogen, and nitric oxide, are employed only during part of the smelting and melting processes.

Having now described the nature of our invention and the manner in which the same is to be performed, we wish it to be understood that we do not limit ourselves to the precise details herein described, as the same may be varied without departing from the nature of our invention; but we claim as our invention the improvements in the manufacture and melting of iron and steel hereinbefore described—that is to say, the use of air charged with the vapor of petroleum or other like volatile oil in blast furnaces and cupolas, for the manufacture and melting of iron and steel; also the use in the blast furnace or cupola of air charged with hypochlorous acid, chlorine, or chlorine and carbonic oxide, for removing sulphur and phosphorus, and the use of air charged with oxygen for rapidly raising the heat of the blast furnace or cupola to the required point for the smelting and melting of the iron and steel, the said gases and vapors being used substantially in the manner hereinbefore described.

THE RESISTANCE OF FLUIDS.

(Continued from page 431.)

RESISTANCE OF THE ATMOSPHERE.

The majority of authors who have treated of the resistance of gas, have admitted that it should be the same as that of a liquid of the same density; hence they have used formulas equivalent to

$$R = W A \frac{V^2}{2g}$$

in which it is assumed that the resistance is proportional to the square of the velocity. The first precise experiments upon the resistance of air are those of Robbins. He caused plates of different forms and dimensions to rotate about a vertical axis, their plane passing through the axis. These experiments were repeated with the same apparatus by Hutton, in 1786 and 1788. Observations of the same kind were afterwards made by Borda, by means of a similar apparatus, the axis, however, being horizontal. Finally, M. Thebault made investigations at Brest in 1826, with Borda's apparatus. The results correspond with those obtained for the resistance of water. For the same body the resistance increases sensibly as the square of the velocity; but more rapidly than the area of the plate, especially when it is near the axis. This is due to the inequality of velocities of points at different distances from the axis. In 1835, at Metz, Piobert, Morin, and Didion, made experiments in which a plane was affected with a uniform motion perpendicular to its direction. These authorities have represented the resistance by the formula

$$R = W A \left(0.03 + 1.357 \frac{V^2}{2g}\right)$$

in which there is a term independent of the velocity. For velocities from 4 to 9

metres, one may neglect this term without sensible error and unite

$$R = 1.357\ W\ A\ \frac{V^2}{2g}$$

Poncelet deduces from all these experiments $k = 1.3$

These authors have experimented upon bodies of different forms; on triedral solids, on cones, hemispheres, and spheres. Unfortunately they have neglected to compare the coefficients obtained with those which thin plates of the same surface as their principal section perpendicular to the motion would give. For spheres, old experiments of Newton and Hutton show that for velocities greater than 8 to 9 metres the value of the coefficient is about 0.54.

The results above mentioned are not applicable to great velocities of artillery projectiles. Bodies moving in the air are attended by liquid bows and sterns (as in the case of motion in fluids) whose volume may be three times that of the projectile. This phenomenon is perceptible in the projection of bombs; which are often seen followed by a dark fluid mass of paraboloidal form; the length being over three times the diameter of the projectile; at the same time the density of the air in front increases rapidly with the velocity. These various causes make the resistance increase more rapidly than the square of the velocity. As the motion of projectiles varies, it is useful to show how one may determine by experiment the law of resistance. It is well known that the velocity of a projectile at any point of its path may be obtained by means of the ballistic pendulum. Experiments are made at two distances, a and a', upon two equal projectiles, shot horizontally with the same charge of powder. The results are the same as if trial had been made upon a single projectile. If a and a' differ little, it may be assumed that the resistance R has not sensibly changed during the interval, and therefore, that the work of this force may be expressed by

$$R\ (a - a').$$

At the same time the loss of living force is

$$\tfrac{1}{2}\frac{P}{g} \cdot (V^2 - V'^2);$$

P being the weight of the projectile and V and V′ the measured velocities. We have then

$$R\ (a - a') = \frac{P}{2g}(V^2 - V'^2)$$

$$\therefore R = \frac{P\ (V - V')\ u}{g\ (a - a')};$$

u being the mean velocity, $\frac{1}{2}\ (V + V')$.

But if k is the coefficient of resistance for the velocity u, and r the radius of the bullet, we have

$$R = k\ W\ .\ \pi r^2\ \frac{u^2}{2g}$$

$$\therefore k = \frac{2\ g\ R}{\pi r^2\ u^2},$$

or putting for R its value,

$$R = \frac{2\ P\ (V - V')}{W\ \pi\ r^2\ (a - a')\ u}$$

a formula which gives k and therefore R.

M. Probert has been led by experiments made at Woolwich by Hutton, and at Metz by himself, to represent the resistance by a formula of the form

$$R = k\ W\ A\ \frac{V^2}{2g}(1 + a\ V)$$

which, according to Didion, may be written

$$R = \pi r^2\ u^2\ 0.027\ (1 + 0.0023\ u).$$

For oblong projectiles with ogee front, of cylindrical body, plane behind, instead of the coefficient 0.027, should be written 0.018, and if the posterior portion is concave, 0,020 should be substituted.

The last formula may be written

$$R = 0.4077\ W\ A\ \frac{V^2}{2g}(1 + 0.0023\ V);$$

V being the mean velocity.

A few words about the resistance of surfaces of parachute or sail form. According to M. Didion, if a curved surface with a head of one-third or one-fourth its length moves in air, convexity in front, with a velocity of from 0 to 8 metres, then the resistance is only 0.77 of what would be experienced by a plane surface of area equal to the projection of the curve surface perpendicular to the direction of motion. But if the concavity is in front, the resistance is 1.94, that of the plane being 1. M. Thibault, in his experiments made on sails with a belly equal to a seventh of their yard, has arrived at the remarkable result that for inclinations greater than 45° the re-

sistance is the same as if the sail were developed into a plane; but it is much greater than for the developed sail, if the inclination is slight. This result seems to show that the elasticity of air plays a more important part than is generally supposed, and that under such inclinations we cannot treat air as a liquid of the same density. Poterat, in the introduction to his "Theorie du Navire," expresses the opinion that, whatever may be the incidence of the wind upon the sail, its action is nearly normal at every point; and he gives many striking examples of the discrepancies between the results of practice and the theory generally adopted. In order to avoid intricate calculations the sails of ships are generally regarded as plane. The real action of wind upon sails, unfortunately as yet little understood, invites the special attention of experimenters and geometers.

A NOTE ON METEOROLOGY.

By PROF. ORAN W. MORRIS.

The law of storms as developed and laid down by W. C. Redfield, Esq., has been tested and is now recognized by our Governmen, in the Signal Service, under the efficient Superintendent, Gen. Meyers.

The law of progression in the temperature may be said to be similar, though not developed as yet; but we think, that upon examination, such will prove to be the case, and as an illustration of the regular onward general movement we will take the month of January, 1871. The maximum temperature of that month in California was on the 3rd; in Montana and Colorado on the 9th; in Illinois, Minnesota, Nebraska and Utah on the 10th; in Missouri and Kansas on the 11th; in Mississippi, Arkansas, Tennessee, Indiana, Wisconsin and Iowa on the 12th; in Vermont, New York, Pennsylvania, North Carolina, Kentucky, Ohio and Michigan on the 13th; in Maine, New Hampshire, Massachusetts, Rhode Island, Connecticut, Virginia and South Carolina on the 14th; in New Jersey, Delaware, Maryland, and District of Columbia on the 15th; in Louisiana on the 24th; in Texas on the 25th; in Georgia on the 30th, and in Florida on the 31st.

Its general course was eastward, while it stretched latterly both north and south, though not down to the Gulf of Mexico till later. There are some irregularities in the movement, but probably owing to local and physical causes.

The movement of the minimum was more irregular, still it confirms the general law, in most respects. The minimum temperature for the same month began on the 3rd in Arkansas, Tennessee and Michigan; on the 4th in Florida, Alabama, Mississippi, Louisiana, Georgia, South Carolina, North Carolina and Ohio; on the 7th in Kentucky and Indiana; on the 9th in Pennsylvania; on the 10th in New Hampshire, Delaware, Maryland and Virginia; on the 12th in California, Montana and Colorado; on the 13th in Utah; on the 14th in Texas; on the 16th in Nebraska; on the 18th, in Minnesota, Wisconsin, Iowa Illinois, Missouri and Kansas; on the 23rd in Vermont, New York, Massachusetts and Rhode Island; on the 24th in Maine and the District of Columbia; on the 25th in Connecticut; and on the 26th in New Jersey.

The groups on the 18th and 23rd were in accord with the progression, if some of the others were not. Further observations may be more regular.

An official report shows that in May, 1870, there were 836 miles of telegraph in actual operation in the Argentine Republic, while 1,000 miles more were in construction. Wires are being carried across the Andes to Chili, and a connection is also to be established with Brazilian and other lines.

One of the strong brick Martello towers at Dimchurch was blown down recently by the Royal Engineers, with a charge of 196 lbs. of gun-cotton.

It is believed that the principal preservative substance used in embalming the mummies of Egypt was carbolic acid in the crude state.

IRON AND STEEL NOTES.

Review of the Iron Trade, 1870–71.—The outlook for 1871 is somewhat mixed and not altogether free from doubt. Our rail mills are most of them supplied with orders enough to occupy them some little time yet. There are, however, others who are open for contracts, and moderate figures would be accepted. There is a notable lack of cash buyers, and there is danger that in the eagerness of competition safety will be overlooked and a load of paper and bonds accumulated, out of which may grow disaster at some future time. It is earnestly to be hoped, however, that an early cessation of hostilities, bringing with it a satisfactory peace, may restore business to its normal condition and obliterate the uncertainty which now hangs over the market.

New Rails.—The import during 1870 has again been large, its proportions being even greater than 1869. During the early part of the year, and until the outbreak of the war, prices of foreign were on a steadily ascending scale, reaching their highest point in June, at which time everything pointed to a prosperous Fall with still higher prices, but the immediate effect of the outbreak of hostilities was to blast at once all such expectations, and the prices have for six months been on the decline, with considerable irregularity, according as the prospects of peace rose or fell. As the market now stands, the margin between foreign rails and those of American make is very wide, and should the war continue much longer, it is evident that the competition must soon become very severe. To meet this successfully, some considerable reduction in material would seem to be necessary even beyond what the reduced price of pig-iron affords.

Old Rails.—The demand for this class of imported material has been large and constant, and prices have advanced during the year from 36s., gold, to 39½ to 40s., with occasional sales at even higher prices. The consumption has been general, with, we think, considerable increase in the area over any former year. Hardly ever has there been any excess of supply, and there is probably no article entering largely into our manufactures which has met so ready a sale, evinced by the large import, which will probably reach nearly 110,000 tons in the aggregate. That this has proved a great boon to our rolling mills is unquestionable, and has neutralized, to a great extent, the inconvenience arising from the inadequate supply of puddled bars; and any increase of the duty, as at one time threatened, would have been a direct injury to such of our mills as are dependent upon the open market for material.

It will be observed that, notwithstanding the increase in the gold price, the equivalent in currency now ruling does not vary materially from that of last year at same time. At that time gold was 120 and rails 36s., equal to 43.20s., against present prices, 39s., and gold 110¾, equal to 43.19s., currency. In quoting these prices we refer to the figures current for DH in round contract lots, for forward delivery, the bulk of the sales having been made in this way. That this should exist in the face of a decline in the currency price of the article made from them is evidence enough of the utility of old rails as raw material. During the past month the demand has slackened materially, and but for the fact that the supply abroad is not plentiful, prices would have yielded. The low price of pig-iron has led many mills to increase the number of their puddling furnaces, and it is evident that the supply from these sources will displace old rails to a certain extent, unless the demand for new rails increase *pari passu*. This will be particularly the case with mills situated at a distance from the seaboard, upon which the inland freight bears heavily.

The price, in gold, of old rails, has been from $35 50 to $39.00 per ton, closing at the latter figure.

Scrap Iron.—The year's trade has been, on the whole, unsatisfactory to importers, and less foreign scrap has in consequence reached the market. The range in prices from yard has been between $37 and $42.50, currency, most of the sales being at about $39 to $40. Our extreme figures were attained only for a short time during May, when the whole stock became concentrated in one or two hands. Scrap iron is always sold in currency, and our quotations invariably represent as near as possible yard prices, as the great variety in the quality of what is offered from dock causes considerable irregularity in prices. As a general rule, however, dock quotations rule from $1 to $3 below these from yard for selected lots.

Pig Iron.—Although the make of American iron has this year largely increased, yet the market has labored under an apparently chronic depression, and prices have declined steadily, month after month, until they have now reached a point below which it is declared they cannot go. Many furnaces of small capacity and disadvantageously situated will probably be blown out, and as the temptation to invest money in this department is not now very great, we will probably witness this year a pause in the onward progress, if not some retrogression in the out-turn of our furnaces. One good feature, however, is the smallness of the stocks, both in the hands of the furnace men and manufacturers, so that we enter the year with fewer burdens and more hope.

In Scotch pig the import has been on a smaller scale than last year, and at times our stock has been very much reduced. The alteration in the duty from $9 to $7 will, in consequence, have less effect, if it has not in a great measure been already discounted, so far as it may influence the prices of the stock now here. There has been, generally, a great scarcity of the best brands, leading to extreme prices being sometimes paid for such, whilst inferior brands would, at the same moment, be difficult of sale. Bessemer pig, so called, has formed a large proportion of our imports the past 3 or 4 months. These have consisted mainly, if not wholly, of the Cumberland hematites, from the Workington, Harrington, Barrow and West Cumberland furnaces. These have been found by experience to be the most suitable irons for the Bessemer process, and the increasing demand for and large extension of the manufacture of steel rails will lead to a large consumption of these brands.—*American Railway Times.*

Experiments on Steel.—For some time past a committee of civil engineers has been engaged in testing the resistance of steel produced by several of the principal manufacturers to tension, compression, transverse strain, and torsion (the necessary experiments having been made by Mr. David Kirkaldy under the instructions of this committee), and the results have now been published. Both funds and material were willingly

placed at the disposal of the committee, and every care was taken that the samples tested should represent the best marketable quality of steel ordinarily made by each of these manufacturers. The results obtained, both with Bessemer and crucible steel, are recorded in a series of elaborate tables, which will prove of the utmost utility to those employing that metal for constructive purposes. Tested by tension, the breaking-stress of hammered Bessemer steel, such as is used for tyres, varied from 29.06 tons per in. to 40.71 tons per in.; hammered Bessemer steel, such as is used for axles, varied from 28.86 to 36.80; hammered Bessemer steel, such as is used for rails, varied from 28.51 to 35.68; rolled Bessemer steel for tyres could bear a breaking stress of 32.09 tons per in.; for axles, 32.22; and for rails, 30.74 and 32.61 tons per in. respectively. The Bessemer steel was in no material degree inferior to crucible steel; for with hammered crucible steel for tyres the breaking stress varied from 30.69 to 40.57; for axles, from 35.72 to 48.13; for rails, 38.14; and rolled crucible steel for axles gave 30.62 tons per in. breaking stress. The ratio of the yielding to the breaking stress is in round numbers from two-thirds to three-quarters.

The committee has also been favored by the Secretary of State for the War Department with a statement of a series of experiments made for the purpose of ascertaining the additional tensile strength resulting from tempering steel in oil and various temperatures, by the officers in charge of the Royal Gun Factory. A record of these is given in the book, as well as of some further experiments on tension and compression of long bars, and for ascertaining the amounts thereof by measuring directly from the bar in order to obtain very accurate results. As to the amount of reliance that may be placed upon the experiments, it need only be stated that the committee consisted of Messrs. W. H. Barlow, George Berkley (who has very ably performed the duties of secretary), John Fowler, Douglas Galton, C. B., and J. Scott Russell, whilst the actual experiments were made by Mr. D. Kirkaldy, to give the fullest confidence that every detail has been carried out with the utmost care and ability. The committee take the opportunity to invite gentlemen who have made careful experiments upon the properties of steel to favor them with the results, and it is cordially to be hoped that the invitation will be freely responded to.—*Mining Journal.*

Smelting Furnaces on a New Principle.—We learn from our Western exchanges that the Union Pacific Railroad Company has built several large iron furnaces for smelting the Wyoming Valley ores, on a new and somewhat ingenious principle, invented by the foreman of the Company's shops. In these furnaces the ordinary fan blower is dispensed with, and the blast of air is obtained by injecting jets of steam into the interior of the upper portion of the furnace. The vacuum thus created draws a blast through the fire with tremendous force, securing all the heat needed to smelt the ore, which does not fuse readily. The furnaces already built on this plan have been running very successfully for several weeks, and others are in course of erection. Foundries are also building, and the Company expects soon to supply itself with all the castings it requires, at a cost much below that at which they have heretofore been obtained from Missouri and the East. The plan of creating a blast of air by means of an ascending column of steam, is not a new one; but its application to smelting furnaces has not, so far as we know, been before attempted, and the improvement thus obtained over the fan-blower may be found important as simplifying the machinery of blast furnaces.—*Iron Age.*

Rolling Railway Axles.—A communication was recently made to the British Association upon a method for shaping railway axles by rolling pressure, instead of by hammering, the result being accomplished in two minutes, instead of half an hour, as required by the usual method; the axle at the same time being not only superior in quality, but more uniform in size, and of course capable of being produced more cheaply. The machine consists of three rollers regulated so as gradually to press more closely together, thus reducing the diameter of the bar, and extending its length until shaped to the size required. Axles of any length can be rolled in this manner with collars at any part. The rollers are geared to revolve all in the same direction, their friction imparting motion to the axle. It was thought by the author of the communication that the rolling process would tend to obviate those flaws in axles which frequently cause disasters on railways.

RAILWAY NOTES.

Continuous Freight Traffic over Lines of Different Gauges.—Mr. Alfred C. Pope, of Binghamton, in a recent letter, says:

In order to facilitate the transfer of trucks in Mr. Noyes' arrangement, I would suggest that the trucks of the cars operated upon should rest upon *turn-tables*, fitted with tracks of the different gauges.

By this means the rejected truck could be disposed of without interference with that which takes its place.

This arrangement for the transfer of loaded cars is apparently the quickest, and certainly safer than the only method now in use. With a yard properly arranged, the transfer can be made in ten minutes with ease and safety.

The first outlay, and the expense of running, need not be heavy, and the great *desideratum*, that of each transportation company keeping the control of its rolling stock, could be perfectly carried carried out.

By this means also the return freight could be expeditiously managed, and if, at any time, it should be desirable to accumulate a large amount of freight for a particular road, it could be readily done, and yet be in shape to be forwarded at a moment's notice.

Hardening of Rails.–At Demitoff's works in Salda Nischne, some years since, it was accidentaly discovered that ordinary iron rails gain essentially in hardness by sudden cooling. Want of room in the mill necessitated the removal of a part of the rails, while still red hot, to the outside of the building where the ground was covered with snow. Subsequent experiments made by the Commission appointed by the Government to test the rails, revealed the fact that the rails thus suddenly cooled were harder than those gradually cooled, and since this time all the mills in Russia harden their rails by cooling in water.

In the works of Von Putilow, near St. Petersburg, rails with mild puddled steel heads are allowed to cool in the air, until they cease to be luminous, before immersion in water; but in all other mills, rails of hard iron are plunged into cold water immediately after leaving the saws.

As these rails are found perfectly reliable in Russia, where the temperature in winter is often 40 to 60 deg. below zero, there can be no question as to their applicability elsewhere.

The danger of fracture in good hardened rails depends obviously only on the *degree* of hardness, and this depends on the amount of carbon present in steely irons, and on the temperature at which the hardening is effected, and there can scarcely be any tenable ground why rails should not be hardened while many other articles are, in which fracture is equally to be feared.

The hardening effected by sudden cooling is indisputably less dangerous than that imparted by phosphorus, and in case of iron free from impurities, when we compare rails hardened on the one hand by the addition of carbon (approaching steel in composition), and on the other by sudden cooling, the advantage of safety would undoubtedly be in favor of the latter—to say nothing of the expense of manufacture.

In this connection may be mentioned that at Salda Nischne, and also at Wolkinsky, a photometer, the invention of Director Palanow of the former works, is in use to determine the temperature of the rails after leaving the rolls, by the amount of light emitted, so that the ends may be sawed off at a constant temperature, thus securing perfect regularity in the length of the finished rails.—*Translated for the Bulletin of the Iron and Steel Association, by Thomas M. Drown.*

Narrow Gauge Railways in Massachusetts.—A joint committee of the Massachustts Legislature have reported a bill to authorize the construction of narrow gauge railways. The bill provides that any branch railway hereafter constructed in this State may adopt a gauge of 3 ft. on the existing gauge or 4 ft. 8½ in., and no other gauges shall be used in this State. Any association of persons, a majority of whom shall be citizens of this commonwealth, and all of whom shall be citizens of the United States, is authorized to locate, construct, maintain, and operate, within the limits of any town in this State, a branch railway with a gauge of 3 ft., with suitable tracks, stations, and equipage; provided, that at a meeting of the legal voters of said town, two-thirds of such voters shall authorize the construction of the road. Upon recording articles of association the association shall become a body corporate, with all the powers and privileges, and subject to the duties and liabilities affecting railway corporations. Any railway corporation now established may locate, and may maintain as a part of its railway system, one or more narrow gauge branch roads, provided the county commissioners where the road is to be located determine that the public convenience or necessity requires it. The bill also makes provision for the transfer of freight from the narrow gauge roads to the existing roads.

Improved Lubricator.—A correspondent in Cleveland writes us that he expects soon to offer to railroad companies "a device that will be very acceptable, yet not entirely new, but almost invaluable in its economy, comfortable character, and adaptation to uneven and curved railroads." He says that he has certificates from prominent railroad men stating as the result of experiments that *one-half* of the expense of lubrication has been saved by it, and hot boxes entirely avoided, and that the saving of time, labor, brasses and motive power has been scarcely less than the saving in oil.

Having thus excited our curiosity, our correspondent makes no attempt to satisfy it, but leaves us and our readers to guess by what means these desirable effects are attained.—*Railway Gazette.*

The Electro-Magnetic Brake in New England.—The Massachusetts Railroad Commissioners in their last annual report, while discussing the Providence & Worcester Railroad, say:

"Upon some cars of this road Olmstead's electric brake has been applied, which may be put in action on any car by itself, or on all the cars on the train at once, from the engine. The power is furnished by a battery in each car; the electric action keys up a loose wheel on the axle, and this winds up a chain attached to the brake. The advantage of this brake over Creamer's, or any other acting by a spring, is that it is always ready for action, and does not need to be wound up every time it has been used. In the experiments witnessed by the commissioners, it did not appear to have any superiority in quickness of action over the common hand brake. The Superintendent of the road, however, stated that this brake had been in use on five cars for two months and had given good satisfaction; that it would stop a train in thirty-three seconds in running not much more than the length of the train."—*Railway Gazette.*

Steel Tires under Brakes.—Mr. T. Rochussen, of London, writes as follows to the London "Engineer" relative to recent accidents on English railroads caused by the breaking of a tire of a wheel:

"Although, during the last twenty years, steel was indiscriminately used wherever practicable in the permanent way and rolling stock of Prussian railways, and its value recognized long before it found root in English practice, it has always been understood that cast steel tires should not be applied to wheels running under brakes, and for this reason: The cast-steel tires, when checked by the brake and skidding upon the railway, get very hot by friction; in pulling up in a pool of water, a heap of snow, or even in a keen draught of wind, a cast-steel tire may, under such circumstances, get a hard chill or brittle temper, and, being so injured and deprived of elasticity, it may break at any time, either while running free or under a brake, and that without giving previous sign of existing danger.

"I may add, speaking from my own knowledge of most of the large steel works in Prussia, that, in contracts for material, manufacturers distinctly stipulate that no guarantee is undertaken for cast-steel tires or disc wheels if at any time used under brakes. The only material admissible in such a position is good fine-grain iron approaching in crystallization to very mild puddle steel, which does not temper by sudden cooling; or, if a bias in favor of steel must be over-indulged, the cast steel should be made especially for the purpose, so as not to contain more carbon than wrought iron, with which it would become identical. Such a tire could be safely bolted to the wheel, and this process would, in the Hatfield accident, have been

less dangerous than the Beattie fastening, which, although designed to hold the tire on to the wheel even when the tire should burst, in this instance failed to answer its purpose.

"The Prussian Board of Trade prohibit the use of cast steel-tires under the brakes of the mail carriages, which, on an average, weigh 17½ tons, and form part of nearly every passenger train throughout the country."—*Railway Gazette.*

NORTHERN PACIFIC.—Work was begun in July last on the eastern portion and the money provided, by the sale to stockholders of $6,000,000 of the Company's bonds, to build and equip to the Red River—233 miles. Several thousand men are at work, and about the 1st of August next this important section will be in operation. In the meantime orders have been sent for the commencement of work on the western end, and the work will be pushed, both eastward and westward, with as much speed as may be consistent with solidity and economy.

The road runs through the following counties: St. Louis, Carlton, Aitkin, Crow Wing, Cass, northern border of Todd, northern part of Otter Tail, western part of Becker, and northern part of Clay. It crosses the Red River a few miles north of Georgetown, and the Mississippi at Brainard, 13 miles north of Crow Wing.

At Thomson, 22 miles from Duluth, it connects with the Lake Sup. & Miss. R.; and near Cartridge River, with the branch of the St. P. & P. (when extended). Branch lines will be built north and south, to drain the entire region north of lat. 42° and render the future construction of additional east and west lines within that belt unnecessary.

Through the first 100 miles from Duluth the road passes through timber; the remainder of the distance to the Red River is alternate timber and prairie—a fine agricultural country.

The present equipment is only intended for the work of construction. None of the gradients are heavy through Minnesota, the general face of the country being level.

Concerning the purchase by the Northern Pacific R. Co. of the two lines of the St. Paul & Pacific R., the announcement in the N. Y. *Tribune* recently, was an authentic statement of the transaction as closed. The Northern Pacific R. Co. purchased from E. D. Litchfield, of London, the main and branch lines of the St. P. & Pac. R.—about 800 miles in length. Mr. Litchfield is to complete the main line to Breckinridge. From this point it will extend to the Missouri. The extension of the branch to Pembina and the British boundary line will be commenced immediately. The principal officers of the St. Paul & Pacific retain their positions. The effect of this purchase is practically to consolidate the two roads, and thus give the Northern Pacific a double eastern terminus—one arm reaching to St. Paul, there tapping the commerce of the Mississippi valley, and connecting with the Illinois and Eastern systems of roads; the other extending to Duluth, where it meets the commerce of the great lakes and the St. Lawrence. The consolidation also removes all hurtful rivalry between competing interests.—*Chicago Railway Review.*

COMPARATIVE COST OF SUPERSTRUCTURE FOR DIFFERENT RAILWAY SYSTEMS.—We make the following extract from a very neat circular issued by M. Baird & Co., of the Baldwin Locomotive Works, of Philadelphia.

The circular presents six photographs of as many different styles of narrow gauge locomotives.

All needful statistics of weights, dimensions, cost, and power are neatly tabulated.

The weights and capacities of the different classes of cars are given in similar manner.

The following is the extract referred to:

The following are comparative estimates of the cost of a mile of single track, properly proportioned for each gauge specified:

1st. For 4 ft. 8 in. Gauge.—Rail 55 lbs. per Yard.

87 tons of rails, @ $70 00 per ton		$6,090 00
400 rail splices, " 1 00		400 00
5,500 lbs. spikes, " 5		275 00
2,640 cross ties, " 80		2,112 00
2,000 cubic yards gravel ballasting, @ 50 cts.		1,000 00
Laying 1 mile of track		500 00
Total		$10,377 00

2d. For 3 ft. 6 in. Gauge.—Rail 35 lbs. per Yard.

55 tons of rails, @ $75 00 per ton		$4,125 00
340 rail splices, " 60		204 00
3,520 lbs. spikes, " 6		211 20
3,520 cross ties, 5 ft. long, 5 x 6 @ 40 cts		1,408 00
1,200 cubic yards ballasting gravel, @ 50 cts.		600 00
Laying 1 mile of single track		350 00
Total		$6,898 20

3d. For 3 ft. Gauge.—Rail 30 lbs. per Yard.

47½ tons of rails, @ $75 00 per ton		$3,562 50
330 rail splices, " 50		165 00
3,520 lbs spikes, " 6		211 20
3,520 cross ties, 5 ft. long, 5 x 6 in., @ 30 cts.		1,056 00
1,000 cubic yards ballasting, @ 50 cts.		500 00
Laying 1 mile of single track		300 00
Total		$5,794 70

4th. For 2 ft. 6 in. Gauge.—Rail 25 lbs. per Yard.

40 tons of rails, @ $75 00 per ton		$3,000 00
330 rail splices, " 50		165 00
3,520 lbs. spikes, " 6		211 20
3,520 cross ties, " 25		880 00
1,000 cubic yards gravel ballasting, @ 50 cts.		500 00
Laying 1 mile of single track		250 00
Total		$5,006 20

5th. For 2 ft. Gauge.—Rail 20 lbs. per Yard.

31½ tons of rails, @ $75 00 per ton		$2,362 50
330 rail splices, " 45		148 50
3,520 lbs. spikes, " 6		211 20
3,520 cross ties, " 20		704 00
750 cubic yards ballasting, @ 50 cts.		375 00
Laying 1 mile of single track		250 00
Total		$4,051 20

Comparative cost per mile of each Gauge.

Cost of 4 ft. 8½ in	track	$10,377 00	standard road used.	
" 3 " 6 "	"	6,898 20	reduction 33½ p	ct.
" 3 "	"	5,794 70	" 44	"
" 2 " 6 in.	"	5,006 20	" 52½	"
" 2 "	"	4,051 20	" 60	"

TRAIN SIGNAL LIGHT.—A signal light, to be attached to the rear of trains, invented by two officers of the Little Miami Railway, has lately been tested on that road. It is thus described: "In the centre of the roof of the rear car of the train, over the rear axle, is placed a square lantern, with alternate panes of red and white glass.

The lantern is connected by means of a shaft with one of the axles in such a manner that eight revolutions of the axle produce one of the lantern. When the car stops, the lantern of course ceases to revolve. Upon each side of this main lantern are two others, also connected with the axle in such a way that when the train is moving forward a solid red light is displayed, and if backing, a solid green light. The engineer of a train coming up in the rear can thus tell, by observing these lights, whether the train before him is moving or at a stand-still, and if moving, in which direction.—*American Railway Times.*

The iron road will enter China to stimulate the production of her multitudinous industries as a basis for enlarged commerce. Recently, the first railroad in China was formally tried by Li-Hung-Chang, Superintendent of Trade and Viceroy of the province of Chili-hi, on his taking charge of the Tien-tsin arsenal, a tramway of some three miles, extending around the establishment. This will, it is inferred, be the parent of a railroad system ultimately as grand in its distances as our own. Li expressed himself as much pleased, and evinced that his ideas are going beyond the "Pekin cart."

Wrought-Iron Railway Sleepers.—Mr. Richard Gammon, of Westbury, has patented a new railway sleeper, which is likely to supersede the whole of those at present in use, expecially in tropical countries. The constructors of our railways in India experience the greatest difficulty in making and maintaining the permanent-way. The dry-rot, and those pests of India—the white ants—destroy everything. Sleepers sent from England creosoted and "pickled" are not protected from the influence of the sun and vermin, and seldom or never last more than three years. It was necessary, therefore, to find a substitute, something not only impervious to the attacks of the insects, but which might be made in this country perfect and ready to be laid down wherever they should be required. Mr. Gammon's sleeper is made up of a number of webs and plates of rolled iron, riveted together, and pierced with bolt-holes for the chairs. This saves about two-thirds of the labor in laying, and leaves but little work to be done by native or other labor. The direct cost is not more than 1s. each above that of the best wooden sleepers, and they are calculated to last ten times as long in tropical countries, and three times as long in Europe. Many eminent engineers and railway contractors, who have examined them, believe they will be the railway sleepers of the future. At all events, the invention is highly ingenious, and likely to supply a great want.

Injectors on Locomotives.—Noticing a statement in an editorial in the "Railroad Gazette" some weeks ago, that we knew of no locomotives in this country running with injectors alone, "Engineering" says:

"If the American locomotive superintendents have yet not tried working these engines with injectors alone, it is time that they commenced. There are hundreds of locomotives without feed pumps running in this country and on the continent, and hundreds of them with one injector, and the cases of failure with engines so fitted are but exceedingly few, compared with those which take place where pumps are used."—*Railway Gazette.*

Locomotive Water-troughs.—Troughs for supplying locomotives with water while in motion have been laid on the Pennsylvania Central Railway, one at Derry and another near Johnstown. The troughs are 18 in wide, 6 in. deep, and 1,500 ft. long. The scoop let down from the locomotive will take up water at the rate of 2,200 gals. from each trough.

ORDNANCE AND NAVAL NOTES.

Iron Ship-building.—The Pittsburgh "Commercial" says: It cannot be denied that Pittsburg has, in her existing facilities for the production of iron, unparalleled advantages for the building of iron vessels. During the rebellion many thousand tons of armor plating for the ironsides and others of the best iron-clads of our navy were successfully manufactured here, at a fair profit, in competition with the bids of Eastern establishments, which had the advantage of railway transportation over the mountains in their favor. In 1864 our Pittsburgh mechanics had contracts also for the construction of four iron-clads for the navy of the United States.

Thirty-one years ago, in the construction of the river steamer Valley Forge, our mechanics made their first experiment of an iron hull, and had the owners of the Valley Forge proceeded to remedy the defects of her construction by another, instead of condemning the material, it is probable that most of the Ohio steamers now in existence would have been made of iron.

Over twenty years ago two revenue cutters, now, we believe, in service on Lake Erie, were built at the Fort Pitt Works, and within a few weeks an iron propeller has been launched, to be employed on the Southern coast. We mention these facts, not as novelties to our home readers, but for the inference that what has been done successfully in the past, may be emulated on a larger scale in the future. The enterprising concern which built the propeller last mentioned, is engaged in the construction of another, and we can assure our seaboard readers it is not the only one that is prepared to receive their orders for either coasting vessels or ships. We are glad also to know that one of our most successful steamboat owners has taken in hand to build, at Pittsburgh, a first-class iron steamboat for the Western waters. These beginnings, small though they be in comparison with the vast field of enterprise which is opened by the present and prospective demand for iron vessels of all sorts, will eventually win for Pittsburgh a share of the business of their construction. Meanwhile, while our shops are "waiting for orders," other cities capable of a more comprehensive view of the future, will have established themselves as the great centres for iron ship-building; Pittsburgh has accomplished grand results by the individual energy and enterprise of her citizens through a long series of years. We are proud of our pre-eminence in the manufacture of iron. Nevertheless, in this our chief production, a dozen petty towns north and west of us have, by means of associated capital, done more relatively to their population and advantages, within the short space of 2, 3, or 5 years, than Pittsburgh in 40 years. Our rival cities in the West, St. Louis and Cincinnati, understand this, as witness the progress made by the former

in the production of iron, and the new enterprise organized in the latter for the construction of iron steamers. If a company shall be successfully established in Cincinnati, with adequate capital to engage in this business, Pittsburgh will find, when too late, that a golden opportunity has been allowed to pass, and her iron interests will suffer a loss which can never be retrieved. If, on the other hand, her manufacturers and business men, by associating their capital, engage at once in the enterprise, her supremacy will be maintained. In addition to the requirements of the merchant service and the Western rivers for iron vessels, a similar demand must be met in the construction of an iron navy for the United States Government. The construction of war steamers in the Government ship-yards must soon be abandoned. The inferiority of vessels built at Government ship-yards, their failure to answer the reasonable expectations of the Navy Department, and the fact that better can be had by private contract at a far less price, is no longer denied, and it only remains to overcome the official reluctance to change. Other nations have abandoned the costly and damaging system of Government construction, and in this, as in the change from wood to iron, the United States, which should have led, must follow. There are in the British navy 97 iron vessels, of which no less than 80 were built in private ship-yards, and only 17 in the yards of the Government.

The consumption of iron in Great Britain for the year 1870, in the construction of vessels, was 250,000 tons. President Lincoln, during the rebellion, recommended the establishment of a naval depot for the construction of iron vessels at some point on the Western waters. For the reasons given above, we do not believe such a depot of construction will ever be established, but for the same reasons which probably led to the recommendation, we believe that the Western waters will be found to be the best region for the reconstruction of the United States navy—and Pittsburgh is the place on the Western waters with most advantages for the business. Whether Cincinnati or St. Louis shall, by superior enterprise, overbalance these advantages or not, depends upon the apathy or the enterprise of our manufacturers and business men.

With some men, the fact that any scheme involving the investment of money is urged upon the ground of a public benefit or necessity, at once closes up their ears and their pockets. Happily this scheme of a great iron ship-yard at Pittsburgh has the intrinsic merit of presenting the strongest temptation in the certain profit which must accrue to the investment. The more carefully the subject is investigated, the more attractive it will appear as a mere business operation. And this being the case, we feel the strongest assurance that if a few of our leading men will organize the ship-building company, all the capital needed will be promptly furnished, and the stock will soon command a premium.

Naval Armaments.—Captain A. E. Scott, R.N., recently delivered a lecture at the Royal United Service Institution upon the subject of naval armaments. The lecturer touched upon a very wide range of subjects, and the lecture was somewhat desultory and disconnected, for which the gallant captain excused himself upon the grounds of his being an over-worked man. He, however, advanced some good points which were appreciated by an attentive audience. After numerous quotations from several of the daily and other papers and comments upon their remarks, Captain Scott touched upon the question of naval drill, observing that on board the Prussian ships the drill was most perfect, and that it required improving in our own navy. He then discussed the probabilities and possibilities of an invasion of England, to meet which he observed we require a greater number of more useful vessels. The object being to prevent the enemy landing, we should have a number of gunboats of the Staunch class, mounted with 18-ton guns, which would place our defences in a high state of efficiency. By uniting our bays and creeks, and by further operations inland so as to render good the approaches for our volunteers, England would be rendered impregnable. The mounting of our naval guns then received a large amount of consideration at the hands of Captain Scott, who has devoted many years to the subject, and who has done real service in perfecting naval gun carriages. Captain Scott's system is now applied on board the Hercules, the Sultan, and other vessels, the highest testimony being borne to its efficiency by gunnery officers. The effect of the introduction of Captain Scott's training gear on board the Northumberland was, he stated, to save the annual expense to the nation of 45 men who were required as extras for that vessel, but whose services were superseded by the training gear in question.

Captain Scott then referred to his turn-table arrangement for working guns, noticing, at the same time, the difficulty he had experienced in getting the Government to adopt his plans, although their adoption had proved them to be so eminently successful. Moreover, the gallant captain further pointed out how that, for all his years of labor and heavy outlay, the Government had not in any way rewarded him, nor had paid one farthing of his expenses. The lecturer then went on to point out what, to him, appeared to be difficulties in the way of fighting turret ships, after which he glanced off to the torpedo question, paying a well-merited tribute to the efficient and seamanlike character of the Harvey torpedo. These weapons, he observed, would probably turn the tide of battle in favor of those nations who employed them. Doubling back upon the turret-ship question, the author complimented Mr. E. J. Reed upon his raised breastwork, which will greatly enhance the value of monitors. Such vessels could be used as hospital ships, and could carry torpedo boats, and doubtless would do so in the future. The question of breech-loading *versus* muzzle-loading guns then came in for notice, the lecturer being rightly, of opinion that the merits of the breech-loading system were over-estimated. If torpedoes were used in future actions—as they undoubtedly will be—Captain Scott observed that ships would require guns to keep them off. In view of this he had designed a new carriage for 20 and 40-pounder guns, and with which we understood the Sultan and the Lord Clyde had been supplied. The object was to arm our iron-clads all round with these guns, which were for rapid use against torpedo boats and other similar craft. But with all the best mechanical arrangements, the lecturer observed that England's supremacy could not be maintained unless we had more intelligence in some of the men of the Royal Navy, but which the present pay of £30 or £40 per annum would never

secure. A vote of thanks was accorded to Captain Scott at the close of his lecture, which, by the way, he stated was only a first instalment on the subject. The second is to follow, and we trust the gallant lecturer will find time to digest and organize his matter between the present time and the delivery of the lecture, for by so doing he will greatly enhance the value of his discourse.—*Engineering.*

ENGINEERING STRUCTURES.

The Darien Survey.—All doubts of the practicability of constructing a ship-canal across the Isthmus of Darien have been dispelled. Surveys made from the Pacific coast during the last month have proved the Atrato-Tuyra route to be perfectly feasible; and I will venture to say that if, within the limits of New York State, a ship-canal were to be cut through a country precisely similar to that which we find here on the Isthmus of Darien, it would be open for navigation in less than 8 years. Since the date of my last letter from the Atrato river, everything has been going on well in the Gult of Darien. The Guard still lies at her old anchorage near the entrance to the Gulf, and the Nipsic makes occasional trips to Aspinwall for the mails or provisions. Good progress is making in the hydrographic surveys, and the final chart of the Gulf will be a valuable contribution to the Bureau of Navigation. Chief Engineer Barnes is still in the interior, pushing on as rapidly as possible over the Paranchito route towards the "divide."

Surveys from the Pacific Side.—At present the attention of Commander Selfridge is directed particulary to the surveys on the Pacific side. On February 5th, a party joined the United States steamer Resaca, Nathaniel Greene Lieut.-Commander, which had been detailed by the Navy Department to join the Darien Expedition in place of the Saginaw, recently wrecked on her voyage to Panama. The voyage down the coast was an exceedingty interesting one ; the scenery though not grand is very picturesque and beautiful. In our course were the Pearl Islands, which in former years yielded vast quantities of the gems from which they derive their name, but a disease has lately attacked the pearl oysters, and, in consequence, diving for them has almost entirely ceased. We entered the Tuyra river through the Gulf of San Miguel, which in many ways is admirably suited to the Pacific terminus of the canal. The river Tuyra is upward of a mile in width, and in its waters the largest ships may float up to a point about 6 miles above Chepigana; the Resaca anchored about a mile above the latter town, in the centre of the stream. On the day of our arrival, Friday, February 17, Commander Selfridge left in a whale-boat, with 4 days' provisions, to make a reconnoissance up the river. During his absence a provision-camp was established in the woods on the northerly shore of the stream, an observatory erected, and a tide-gauge placed in position. The tide here has a rise and fall of from 15 to 20 ft., and the current in the river runs from 3 to 4 miles per hour. The banks are formed of a slimy clay, with boulders and shingle of quartz and flint.

After an absence of 3 days Commander Selfridge returned to the ship, having explored the river as far as Pinogana. He found that it did not narrow down until he passed Alligator Island, 18 miles from the ship; thence upward its course is so winding that, while the distance from Chepigana to Pinogana, travelling by boat, is about 45 miles, astronomical observations show that a straight line connecting the two points would be only about 22 miles long. From Chepigana to the junction of the Tuyra and Chuquanaqua rivers there is not a settlement of any kind. Primeval forests are on either bank of the river, and these, at night, are frequented by vast numbers of monkeys, which fill the air with the most piercing shrieks. The only signs of life by day are the alligators and herons. The former are always seen at low water sunning themselves upon mud-banks, from which, when disturbed, they glide into the water with distended jaws, and sometimes they stayed about the boat for several minutes. About 2 miles above the junction is the town of Santa Maria ; 7 miles further on is Mollineca, from which Pinogana is only 3 miles distant. Throughout its whole course the river runs between perpendicular banks from 10 to 20 feet in height. Not a hill of any description is met with, notwithstanding the fact that the present maps of the country represent it as traversed by range after range of high mountains. The country is apparently perfectly level, but it undoubtedly has a slight elevation toward the interior. For agriculture it is remarkably good, but owing to the indolence of the natives it is unimproved. A few days after the return of Commander Selfridge he started out with the first surveying party, which is under the military command of Master Eaton. All work connected with the survey is under the direction of Assistant Engineer Duvoll, assisted by Ensign Wiley. The party, as it left the ship, consisted of 27 persons, all of whom embarked on the steam launch, which had in tow a large flat-boat, with one week's provisions. At Pinogana the launch could go no further on account of shoal water. The party, with provisions, were stowed away in 3 large canoes, in which they made the ascent of the river as far as its junction with the Cue. There a hut was built in which to stow the provisions, and, after a day or two of rest, the survey began. Running a line of levels in this county is a slow process. The machetta men can cut only about 3,000 ft. per day, and they must, of course, always remain in advance of the instruments.

Other Routes under Examination.—Mr. Duvoll is instructed to proceed up the Cue valley until he reaches the "divide," or meets the party of Mr. Barnes from the other side. Every night signals are to be made and firearms discharged by both parties, so that, if within hearing distance, they may come together. In regard to the Cue route, I am able to state, from information received from Commander Selfridge, that it is one over which a white man has never passed. Gorgoza, who explored the Isthmus some years since, never crossed the "divide." He went only to the Indian village of Paya, after which he retraced his steps to San Miguel Bay. The Cue river is a tributary of the Tuyra, and runs through a valley which bears its name. A route up this valley, across the "divide," will connect with the Paranchito, which, by personal observation, is known to be much lower than the Cacarica. The two parties will probably meet in the course of 2 or 3 weeks, and the object for which the Darien Expedition was organized will be accomplished. The length

of the proposed canal is less than 50 miles. About 30 miles of it will be through a country which is apparently "dead level." The greatest elevation in the remaining 20 miles will not be over 150 ft., and it is believed that a point in the "divide" may be found where it will not be more than 75 or 100 ft. in height. A report having reached us that it is only a 6 hours' walk from the Naipipi river, which flows into the Atrato, across a range of hills 400 ft. high to the Cupica river, which empties into Cupica Bay, Limon Bay, and the Pacific Ocean, Commander Selfridge went in the Resaca to examine the route. No one has much faith in the statements of our native informants, and the examination is made in order to settle the thing one way or the other. Before leaving the Tuyra Master Kelly was sent to Pinogana with 6 weeks' provisions for the surveying party in the interior. His instructions are to dispatch 600 lbs. of food weekly to the junction of the Cue river; thence it will be carried in "packs" to the end of the line.—*N. Y. Tribune.*

Proposed Tunnel from Boston to East Boston.—The necessity for freeing the ferries between the above places is rather doubtful. A design for a tunnel between East Boston and the city proper has been prepared, under the direction of Major-General Foster, of the United States Engineering Department. The submarine portion of the tunnel is to be constructed of brick, arch-shaped, laid in a trench and enclosed in a wrought-iron skin or tube. It is proposed to lay two of these tubes, each having an outside diameter of 26 ft. and an inside diameter of 21 ft., so that horse-cars and teams, as well as foot passengers, can move each way at the same time. Leading to these tubes on either side are to be archways of brick. The Boston proper entrance to this tunnel or archway is to be on North street, near its junction with Garden Court street; the East Boston entrance will be from Maverick square. The estimated cost of construction is as follows:

Excavation	$328,723 70
Back-filling	54,309 86
Masonry	722,348 50
Iron work	645,483 45
Timber work(sidewalk)	11,772 00
Paving	43,175 00
Laying of iron tube by submarine (310 sections)	165,000 00
Total	$1,971,062 01
Contingencies (10 per cent.)	197,107 99
Grand total	$2,168,170 00

The present cost of the ferries is about $1,000 per diem, or say $350,000 per annum. The interest on the cost of the 2 tunnels, at 6 per cent., would be only some $125,000 yearly, showing a saving of some $225,000 yearly by the construction of the tunnel.

Concrete and Iron Bridge.—A new bridge erected for Sir Shafto Adair, from the designs of Mr. H. M. Eyton, of Ipswich, over the Waveney, at Homersfield, England, has been recently tested. In designing the bridge advantage was taken of the principle of Messrs. Phillips' patent fire-proof construction, a system in which all the ironwork is completely embedded in Portland cement concrete. The bridge has one arch of a clear span of 50 ft., with a rise of 5 ft. 3 in The skeleton of the bridge is of iron, and this is entirely filled with Portland cement concrete, and rendered with Portland cement, thus forming one continuous beam, getting stronger every year, in addition to the iron skeleton, which is of itself sufficient to do the ordinary statical work of the bridge; the weight of concrete alone is over 100 tons. The spandrels of the bridge are relieved by a raised pannel, and in the centre is a casting of the Adair arms, taken from the old three-arched brick bridge. The first test applied was that of a five-ton road roller drawn by four horses. This was passed across several times, and not the least deflection was perceptible. Afterwards a heavy wagon, laden with sacks of flour, weighing altogether 6 tons, was passed over, and still, it is stated, no deflection could be noticed.—*American Railway Times.*

Road Steamers.—Notwithstanding the stupid restrictions on the running of steam carriages on roads, such as walking with a red flag in front of them, they are making progress. The recent severe frosts have put these steamers, which have lately begun to rise in public opinion, to a severe test. Happily, it is said, they have gone through it successfully. Mr. White, of Kettock s Mill, near Aberdeen, worked his road-steamer regularly throughout the frost. It runs between the mills and the town, a distance of three miles, part of which has a rising gradient of 1 in 10. Up this steep incline the road-steamer bravely drew a load of 7 tons, though the road was covered with solid ice. The wheels of these steamers are covered with india-rubber tires, and as india-rubber does not slip on ice, the steel guards are removed, and the engines do not slip. The question is a very important one as regards the practical value of the steamers, as they can now be used for regular traffic in very cold countries, such as Russia and Canada, where sledging is commonly employed. The india-rubber tires run over almost any kind of surface, and can consequently, it is believed, be used on the dry hot hands of India as well as on frozen roads.

Thompson's road-steamers are about to be brought into use in India. It is intended to run them between two stations in the Punjab, viz., Rawul Pinde and Jhelum, 68½ miles apart. The boiler is on the vertical principle, by which means a nearly uniform water level is maintained when either ascents or descents are being made, a thing in itself of great importance. The india-rubber tires are about 4½ in. thick, and flatten with the weight of the engine, thus giving great adhesion and elasticity on bad roads. The engine runs on 3 wheels only, and in this way a small wheel base is obtained and great facility given for steerage. This train will, on ordinary occasions, consist of one, and on extraordinary occasions of two, omnibusses, and will run the distance in 7 hours, inclusive of all stoppages. One omnibus will carry 20 first, 20 second, and 20 third class passengers, with 50 cwt. of mails and luggage, which will be sufficient for every day traffic. The steamers are well known in the streets of Edinburgh.—*Builder.*

The water works tunnel at Buffalo has been extended 60 ft. into the lake. The tunnel is to be 9 ft. in diameter and over 700 ft. long.

NEW BOOKS.

TABLES OF LOGARITHMS AND ANTILOGARITHMS TO FIVE PLACES, with Marginal Indices for Instant Reference. By E. ERSKINE SCOTT, Actuary and Public Accountant. C. & E. Layton.

This book is the earliest of a class. It should be called "ledgered logarithms." The phrase "marginal index" does not convey that protruding margin, which, like the *ledgering* of the index of a ledger, enables the searcher to turn to his letter at once. And the tables of logarithms and antilogarithms are separate, each having its ledger. But another new feature presented by this table is that it gives *every* 5 figures with their 5 figures of logarithm or of antilogarithm, so that there is no interpolation whatever. And, though not very important, the fifth figure is always correct.

For instance, we want the logarithm figures for 18463. In the common table, we *do dictionary* until we have found 1846, and we find 26623 with a tabular difference of 24. Our fifth figure is 3, and by a small head-multiplication we find 7 has to be added to 26623; this gives 26630. In Mr. Scott's table, we take 18 on the black ledgering (the antilogarithms have red), turn up its page, and we see all that begins with 18; 18463 gives 26630.

Again, suppose we had wanted the primitive figures to 26630, we turn up the page by help of 26 in the red ledger, and 26630 gives 18463.

We have then logarithms without turning of leaves or calculation of proportional parts. But where is the use? Can we not whip off a logarithm quite as quickly in the common way? No doubt, if logarithms were never wanted more than one at a time, we might as well mount a siege-gun to shoot a solitary franc-tireur as set Mr. Scott's table going. But when a job of calculation requires scores or hundreds of logarithms, the saving will be very perceptible with practice. The use of the table may be entirely managed with the left hand, so that the pen need never be out of the right hand. This is something.

In the article "Tables," of the "English Cyclopædia," the ledgering is recommended; and, from some little trial, it is expected that no greater improvement has been suggested since Briggs first made his substitute for the Napierian form. If this assertion be incorrect, we should be glad to know what the intermediate process is by which it can be contradicted. We could say much on the subject, but to those who are not to use these tables, it would be unnecessary; and to those who are to use them, very unnecessary indeed.—*Mechanics' Magazine.*

A NEW MANUAL OF LOGARITHMS TO SEVEN PLACES OF DECIMALS. Edited by Dr. BRUHNS, Director of the Observatory, and Professor of Astronomy at Leipzig. 8vo. B. Tauchnitz, Leipzig. 1870. D. Van Nostrand, N. Y.

The arrangement of these tables is in many respects similar to that of Bremiker's excellent edition of Vega's seven-figure logarithms. The type is larger and clearer than that of Bremiker, being of the same Old English form. We agree with the editor in preferring it to the Egyptian type of Schrön, the only serious objection which we should urge to it being the liability to call 6 or 9 by mistake a zero. For the first 6 deg. of the octant the sines, cosines, tangents and cotangents are given to every second, whereas in Bremiker only sines and tangents are given, and that only for 5 deg. For the remaining 39 deg. they are given to every 10 seconds. Wherever space allows, the proportional parts of differences are inserted in the margins of the parts. The arrangement of the pages in these 39 deg. is like that of Bremiker, except in putting sines and cosines in *adjoining* columns. The arrangement for the first 6 deg. is quite different from and is better than that of Bremiker. Extraordinary care, it is claimed, has been taken to secure accuracy in printing, and the logarithms of the circular functions were independently computed, as well as compared with established tables.—*American Journal of Science.*

MODERN PRACTICE OF THE ELECTRIC TELEGRAPH: A Handbook for Electricians and Operators. By FRANK L. POPE. Fourth edition, revised and enlarged. New York: D. Van Nostrand, 23 Murray street.

Although it is less than two years since this work was originally published, it has already become the standard treatise on American Telegraphy. For this reason we are glad to see that the enterprising publisher has brought out the present edition in a style much superior to its predecessors, and with corrections and additions which largely increase the practical value of the book. Even within the comparatively short time which has elapsed since this book was first written many new facts in regard to telegraphic practice, which had hitherto escaped notice, have been brought to light by the careful investigations of such men as Farmer and Brooks. This has been noticeably the case with regard to insulation and the arrangement of batteries.

Every year's experience of our best telegraphers is leading them to the inevitable conclusion that the fundamental defect of the whole system—in fact, the root of all the innumerable evils that telegraphs are heir to, is in defective insulation. A quarter of a century has been spent in unavailing efforts to palliate or avoid its effects, while the cause itself remained comparatively untouched. Self-adjusting relays, low resistance relays, enormously heavy conducting wires, and a half a hundred other devices have been successively heralded as the great specific remedy; but one by one the intelligent and thinking class of telegraphers are becoming convinced that all this is the merest empiricism and quackery. The disease itself must be rooted out. When our lines are once thoroughly and completely insulated it is an easy matter to dispose of every other difficulty that may arise. That these considerations have not escaped the notice of the author is evident from some changes which have been made in the original text, as well as the character of a portion of the new matter which has been added. Thus, on page 58 of the former editions, we read: "Experiments show that soot will destroy the surface insulation of even the best insulators, unless exposed to the cleansing action of the rain. Two years of experimenting have evidently impressed upon Mr. Pope's mind the undoubted fact that the "cleansing action of the rain" does not help the matter much, for in rain the outer surface of the insulator, though clean, is wet, and therefore a conductor, while the inside is both dirty and wet and also a conductor. He now says "even when exposed to

the cleansing action of the rain." An important difference, as will readily be perceived. Again, on page 63, referring to the English system of attaching earth wires to the poles, to cut off cross currents, the old editions remarked that "this practice might be adopted in this country with great advantage to the working of the line." The author has now arrived at the eminently sensible conclusion that, instead of adopting the practice referred to, "a much more economical and effective method of obtaining this result is that of improving the insulation."

Chapter IX is composed entirely of new matter, relating to "Recent Improvements in Telegraphic Practice." Considerable information is given in regard to the newly invented "compound wire," and the "gravity battery," in its different forms. This, we think, is undoubtedly destined to be the universal telegraphic battery of the future, and the author, evidently foreseeing this, has given a concise but correct description of the battery, and directions for its management, which leave little to be desired in this respect. The Siemens Galvanometer, a very recent European invention for testing the lines, etc., is well described, and its principles illustrated. This instrument has met with a remarkable degree of favor in this country, some fifteen of them being already in use here with the most satisfactory results, although it is not a year since its first introduction. The Pope and Edison type printer, for private telegraph lines—another new and successful invention—is described and well illustrated. Nothing is said about the new automatic system which is exciting so much interest, probably because its details are not sufficiently complete to admit of a careful description.

A very valuable chapter on "the Equipment of Lines," a much neglected point in scientific telegraphy, has been added to the Appendix, and will excite much attention and perhaps some discussion among those interested. The recommendations contained therein certainly differ very widely in many cases from present practice. The portion relating to the arrangement of sounders and registers, in connection with their batteries, is excellent. The credit of the latter investigation was due originally to Mr. Brooks, and we are glad to find that Mr. Pope has embodied it in a permanent form. "The Working Capacity of Telegraph Lines" is a treatise on insulation in disguise, and a good one, too. There is food for much study and reflection in this article.

We are glad to see Ohm's method of geometrical projection, as applied to telegraphic circuits by Webb, embodied at length in a permanent form. It is curious, interesting, and valuable, and will be better appreciated a few years hence than it is now.

A great defect in the former editions of this work was the lack of an index. This has been supplied in the present one, and it is needless to say adds greatly to its value. These additions and improvements, as well as the handsome style in which the publisher has brought out the work, will no doubt insure it a continued and increased popularity among American telegraphers.—*The Telegrapher.*

THE YOUNG MECHANIC. A Book for Boys. Trubner & Co., London. For sale by Van Nostrand.

This little hand-book is a good manual of applied science for boys. The use of tools of all kinds is well described, as is also the precise manipulation to secure good work in lathe turning of different materials. The method of making miniature steam engines and other models is also fully given.

A LABORATORY TEXT-BOOK OF PRACTICAL CHEMISTRY; or Introduction to Qualitative Analysis. By W. G. VALENTINE. London, 1871. For sale by Van Nostrand.

THE STUDENT'S ELEMENTS OF GEOLOGY. By CHAS. LYELL. London, 1871. For sale by Van Nostrand.

No other writer on this science has made the subject so attractive to the general reader as this author. The illustrations in the present volume are abundant, there being 600 in all.

THE ESSENTIALS OF GEOMETRY. By J. R. MORELL. London: Griffith & Farran. For sale by Van Nostrand.

This little book is the result of a demand for some shorter route to the applications of geometry than is afforded by Euclid or his followers. To the teacher of mathematics the book will appear unsatisfactory. Such demonstrations as the book contains would hardly be considered beneficial to a student under mathematical training.

There is no doubt but that the French and German methods of teaching geometry are far better than ours. Euclid's methods, upon which our modern authors base their own systems, were spun out with reference to meeting all possible cavils rather than to instil the essential truths of the science.

Mr. Morrell's contains many good suggestions, but it will not succeed with instructors in its present form.

THE ANNUAL OF SCIENTIFIC DISCOVERY FOR 1871. Edited by JOHN TROWBRIDGE, S. B. Boston: Gould & Lincoln. For sale by Van Nostrand.

The bare announcement of the appearance of this book serves as a sufficient notice. All readers of science keep the series at hand for reference.

The present number is not behind its predecessors in the variety or scientific value of its articles.

The notes by the Editor form a good introduction, and present a fair summary of scientific invention and discovery during the year.

The articles are carefully selected from a wide range of scientific periodicals, and it may be safely assumed that no important additions to our scientific knowledge have escaped record. On the other hand, the Editor has excluded all claims to discovery whose genuineness is at all doubtful, although the opportunities for gathering such have been frequent during the last few months.

Everybody needs the Annual.

PRELIMINARY EXPERIMENTS ON THE MECHANICAL AND OTHER PROPERTIES OF STEEL MADE OR COLLECTED BY COMMITTEE OF CIVIL ENGINEERS. London: Adams Brothers.

This is a pamphlet containing tabulated results of 203 experiments on the properties of steel, made under the direction of Mr. Kirkaldy.

The results are of great interest to all who use steel.

The experiments are upon tempered and un-

tempered specimens, and upon a great variety of brands. The figures alone are given ; no theory is discussed, and there are no more remarks than serve to elucidate the tables.

Gun Carriage for Heavy Ordnance. Invented and Patented by Capt. John Wall Wilson, U. S. R. M. New York. 1870.

A small duodecimo in neat form, containing a large folding lithograph of a carriage, designed for a 100 lbs. Parrott gun. The descriptive text is supplemented by letters from savans and experts on the merits of the materials and in the conconstruction, and also upon the success of the invention as a whole.

The Prussian Infantry of 1869. Translated from the German by Col. Henry Aime Ouvry, C. B. London: Mitchell & Co. For sale by Van Nostrand.

This is a well printed pamphlet of 120 pages, containing a complete discussion of the theory of the Prussian infantry tactics.

MISCELLANEOUS.

The Pacific Submarine Cable.—The Committee of the Chamber of Commerce charged with the subject of Telegraphs and Postal Affairs, of which Samuel B. Ruggles is chairman, reported on the 20th of December last the following resolution, which was adopted :

Resolved, That the Chamber of Commerce of the State of New York regard a well-regulated system of telegraph, by sea and by land, as a matter of primary importance to the interests of this country and of the world, and respectfully ask that Congress may pass, at an early day, such laws as will, without creating any monopoly, facilitate the laying of a submarine cable across the Pacific Ocean, from the western coast of America to the eastern coast of Asia, thereby completing, with the lines now in operation, and with those soon to be laid, telegraphic communication around the world.

The committee now report upon (1.) The locality and length of the telegraphic lines already established, and of those which are still needed to complete a communication around the globe. (2.) The influence of the work, when completed, upon the commerce of the world, and especially the commerce on the Pacific and the Indian Oceans.

Locality.—The telegraph line, when completed, will necessarily embrace the 360 deg. of longitude encompassing the globe. This great circle is divided into two segments, unequal in length, but each containing a continent and an ocean. The Western embraces the Western Continent and the Atlantic Ocean, extending from San Francisco, in California, to Valentia, in Ireland, over 112 deg. of longitude; while the Eastern embraces the Eastern Continent and the Pacific Ocean, extending from Valentia to Shanghai, in China, over 132 deg. of longitude, and thence across the Pacific Ocean, over the remaining 116 deg., thus completing the entire circle of 360 deg. Of these two segments of this great terraqueous line, the Western, from San Francisco to Valentia, has been finished largely, if not mainly, by the energies of the citizens of the United States. Of the Eastern segment, the portion crossing the Eastern Continent is now nearly completed. Two continuous lines extend eastwardly from Valentia, one inclining to the north through the United Kingdom, Germany, European and Asiatic Russia, to the present temporary terminus at Kiachta, an important Russian entrepot in Eastern Siberia, near the Chinese frontier, in north latitude 51 deg.; while the other pursues a southeasterly course through France, Austria, Turkey, Persia, and other Asiatic countries, to Bombay, in Hindostan, and thence by way of Ceylon to Singapore, only 1 deg. 30 min. north of the equator. Kiachta is 116 deg. and Singapore 113 deg. east from Valentia. The land line through Turkey and Persia being liable to occasional interruption in regions only partially civilized, a submarine line has also been laid from Italy through the Mediterranean Sea, the Red Sea, and the Arabian Sea to Bombay.

By the lines above described commercial and other messages are now regularly telegraphed, without interruption, from London to Kiachta and Singapore. Through the commercial house of A. A. Low & Brothers, of New York, largely engaged in the trade of China and Japan, the committee have ascertained that the extension of the submarine cable from Singapore to Hong Kong about 1,400 miles, and thence to Shanghai, about 1,000 miles, is in active progress. By a letter recently received by Mr. Cyrus W. Field, and exhibited to the committee, they are informed that the line from Singapore to Hong Kong will be laid by the first of May, and be in actual operation by the first of June next. An Australian line will be completed to Singapore within the present year.

Two telegraphic lines under the Pacific have been suggested to the committee :

One commencing at San Francisco, in latitude 37 deg., and deflecting southwardly to the Sandwich Islands, in latitude 20 deg., and thence inclining northwardly, by way of the Midway Islands, in latitude 27 deg. north, to Yokohama, in Japan, in latitude 35 deg. north, and thence southeasterly to Shanghai, in latitude 32 deg. Its length will be 5,430 nautical miles from San Francisco to Yokohama, and from Yokohama to Shanghai 1,035 miles—in all 6,515 nautical miles. The other and more northern line will extend from San Francisco along the coasts of British Columbia, Alaska, and the Aleutian Islands, to the eastern coast of Japan, and thence to Shanghai.

The report considers quite at length the influence of a Pacific cable on the foreign commerce of the world. The total foreign commerce of the European and American nations, in which is included all their commerce with the Asiatic countries, consists as follows : Commerce of the European nations, $7,203,390,415; that of American nations, $1,640,822,697 ; total, $8,844,213,112. The aggregate value of the commodities actually moved is one-tenth of the $8,844,213,112, or $884,421, 311, and one-half of the residue, $7,959,791,801, being $3,979,895,901; the total is $4,864,317,212. The commerce of the Pacific and Indian Oceans is next considered. From the detailed statements in the table the following general facts will appear :

(1.) Of the commerce of Europe and America with Asia, on the Pacific and Indian Oceans, being, in 1868, $735,141,550; the three maritime powers, the United Kingdom, France, and the United States, had $672,103,550, and (2) their commerce on those oceans in 1854 was $330,079,742, showing an increase in the 14 years of $342,-

023,808, being 103 per cent., or 7.35 per cent. yearly. (3.) From the proportion of exports to imports shown by the tables of the three nations, we may safely estimate that of the total commerce of $735,141,550 the exports to the Asiatic countries did not exceed $300,000,000, so that the imports from these countries were at least $435,141,550. (4.) Of the last named amount, Australia and New Zealand furnished $62,942,240, and the more tropical countries of Asia the remaining $372,199,310. It is this last portion which imparts to the commerce on the Pacific and Indian Oceans its peculiar interest.

The conclusions to which all these facts lead the committee are in brief these: It surely requires no great stretch of imagination or credulity to believe that a commerce so beneficent and civilizing, in a world like ours filling up with people so rapidly, is destined to large and speedy increase, especially if wisely aided by our National Government. It is not for the clear-headed, far-sighted merchants of the United States to close their eyes upon the fact that, in the providential march of events, a field so vast is just opening to their well-directed energy. The products of the globe will take the shortest and cheapest road to market. San Francisco will be the entrepot for a vast part of the Oriental trade, and should therefore be speedily put in telegraphic communication with the continent of Asia.

Improved Safety Lamp.—A miner's safety lamp, possessing several novel features, and designed for the burning of paraffine oil, has just been invented by Mr. William Simpson, of Battersea; and from the report made upon it after practically testing it in a mine, it is probable that with some trifling modifications in detail, it will thoroughly answer the purposes for which it is intended. The oil-chamber is of annular form, the passage through the centre being carefully covered at the bottom with wire-gauze. A bridge across the upper end of the opening connects the oil-vessel with an ordinary flat-wick paraffine burner, provided, however, with an automatic extinguisher, to prevent the exposure of the flame by the opening of the lamp. This extinguisher is extremely simple, consisting of two small plates, which, whilst acted upon by the spring provided for that purpose, cover the wick and wick-tube; but whilst the lamp is in use this spring is held back by a catch in such a manner as to be once released upon any attempt being made to unscrew the lamp top. The vastly superior light and greatly increased economy of paraffine oil, as compared with candles, is so well known that it need not be referred to; and if Mr. Simpson can succeed in introducing his lamp into collieries, colliers will have no excuse for opening their lamps to increase their light. The new lamp, as at present constructed, is 18 in. high, and 4½ in. diameter, and is provided with a tripod 2 ft. high in which the lamp is suspended, in order to prevent the possibility of it assuming anything but a vertical position when it stood upon the floor of the mine; future specimens, however, will be made 4 in. shorter, so as to approach more nearly the size of the lamps at present in use. The price of the lamp and tripod complete will not exceed 8s. 6d., which is rather under than above the price of a good Stephenson, so that expense will be no bar to its adoption.

The lamp has been thoroughly tested by Mr. J. Morton, mining manager to Young's Paraffine Light Company, Glasgow, and his report upon it is decidedly favorable, although he suggests several modifications, which he considers would improve the value of the lamp, which he states he found to have several advantages and also several serious objections. He first examined a working-place with a Davy lamp, and found it to contain fire-damp along the roof, 1 ft. deep, about 6 ft. in length, and 4 ft. in breadth. He afterwards took the paraffine lamp, and could not by any means detect fire-damp, on account of the extra height from the flame to the top of the lamp, it coming in contact with the roof, before the flame was allowed to come in contact with the fire-damp. He then put the two lamps alongside of each other, and found it the same as before, viz.:—Fire-damp in the Davy lamp, and no appearance in the paraffine lamp. He afterwards laid aside the Davy lamp, and raising the paraffine lamp to the roof, he slowly waved his hand, and brought the fire-damp down upon the flame, when a slight explosion took place inside the lamp, exactly similar to what happens in the Davy lamp under the same circumstances. The outside gauze after this experiment was perfectly cool. He next tried it in a strong current of air coming direct from a small pair of fanners, and found it to have no visible effect on the flame, whereas a naked light put alongside of it was completely extinguished, thus showing to what advantage it could be carried against a strong current of air with perfect safety, although the air might be mixed with a large proportion of fire-damp. He is, therefore, of opinion that it is a first-class lamp, in fact, superior to anything that he has seen, for workmen who might be required to work in a place, containing a small proportion of fire-damp, as owing to its superior light they could perform their work with nearly as much freedom as with a naked light, and with comparatively perfect safety, and would be of invaluable use in any large mine, where nothing but safety-lamps were used by the workmen; but it is not at all suitable for a fireman examining the working faces of a mine, owing to its deficiency in detecting fire-damp in the small cavities and fissures of the roof, and could not be used for that purpose. If there was any possible way of conducting the flame on a white heat to the top of the funnel so that it would come in contact with the fire-damp at that point, it would obviate the most serious objection, and altogether change the qualities of the lamp—in fact, would make it superior to any safety-lamp at present extant.

Of the great illuminating power of Mr. Simpson's lamp there can be no question; and as he appears to have already succeeded in removing the defects, without lessening its advantages, it may be anticipated that more will soon be heard of it.—*Mining Journal.*

Russia and China.—Indian papers state that a Russian line of steamers is to be put on the Odessa and China line, *via* the Suez Canal, for the transport of tea and other merchandise to and from Southern Russia.

In Belgium furnace slag is now utilized by allowing it to run off into moulds along the sides of the furnace, in which it assumes the form of rectangular blocks of any size. When cold, the mass forms a compact, homogeneous slag, very much resembling porphyry, and is well adapted for building and engineering purposes.

CAPTAIN ERICSSON'S DYNAMIC REGISTER.

PAGE 561.

FIG. I.

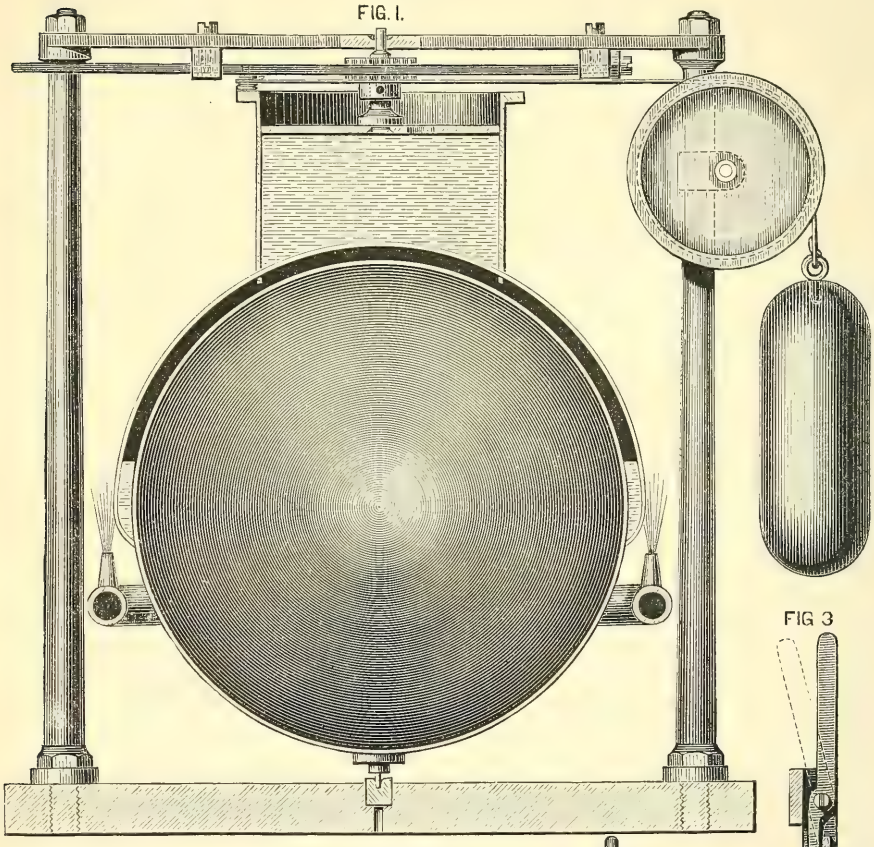
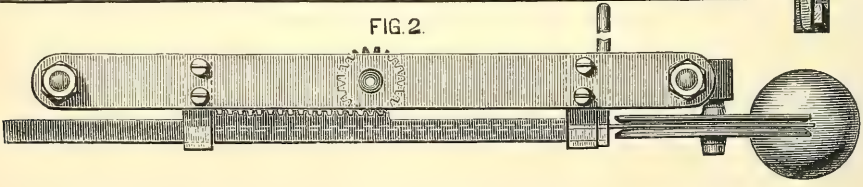


FIG 3

FIG. 2.



VAN NOSTRAND'S
ECLECTIC
ENGINEERING MAGAZINE.

NO. XXX.—JUNE, 1871.—VOL. IV.

SOLAR HEAT—ITS INFLUENCE ON THE EARTH'S ROTARY VELOCITY.

BY CAPTAIN JOHN ERICSSON.

(*Continued from page 475.*)

(*See Frontispiece.*)

The last column of the table accompanying the previous article on this subject contains, it will be recollected, the amount of retardation caused by the waters of rivers flowing towards the equator. The computation of the retarding energy being based on the weight of water discharged and the increase of rotary velocity acquired during the transfer from the source to the outlet, no question can be raised as to the existence of the retardation entered in the table; but, whether compensating energies are called forth by the returning vapors before the condensation takes place, which results in the precipitation on the river basins, demands careful consideration. Dr. Mayer, in his discourse previously adverted to, positively asserts that, agreeable to the demonstration of Laplace, based on abstract mechanical principles, the compensating energy corresponds in every instance, with the amount of retardation to which the rotary motion of the globe may be subjected. Admitting this conclusion to be correct, we must assume the adequacy of the *vapors* which rise within the tropics to restore, during their transfer, to the temperate and polar regions, the loss of *vis viva* occasioned by the *water* flowing towards the equator. Obviously such restoration of energy can only be effected by friction or pressure of the vapors against projections on the earth's surface, directly or through the intervention of particles of the atmospheric air put in motion by the vapors. The Astronomer Royal of Sweden, in a recent communication to the Royal Academy of Sciences at Stockholm, in refutation of my assertion that solar influence is capable of diminishing perceptibly the rotary velocity of the earth, thus states the case: "The globe and its atmosphere constitute a combined system in motion, in which no part can by any outside cause be disturbed in its relative position without the motion of the entire system being thereby influenced. Consequently, a body of air which, for instance, is carried from the direction of the equator toward either of the poles, must, by degrees, positively part with the excess of rotary *vis viva* which it possessed at the commencement of the motion, compared with the rotary velocity of the region to which it has been transferred, and must impart the entire surplus to the earth undiminished, the rotation of which must consequently be accelerated by this current of air; and conversely a current of air of contrary direction, or from either of the poles towards the equator, must produce retardation. No difference can exist in this respect be-

tween a current of water and a current of air." The Swedish Astronomer, like Laplace, thus puts the whole question in a nutshell, asserting that air and water, water and air, may circulate in any manner whatever between the equator and the poles, and between the poles and the equator, without influencing the axial rotation of the globe. It is very true that the earth, with its rivers and atmosphere, constitute a "combined system in motion;" but we must not lose sight of the important fact that an *outside* energy, the sun's radiant heat, is being continually exerted, which interferes with the motions within that combined system. Accordingly, no argument can prove the correctness of the statement laid before the Royal Academy of Sciences at Stockholm short of a positive demonstration, showing that particles of vapor corresponding in weight with the water discharged by some river—say, the Mississippi—are capable of imparting by friction against the earth's surface, directly or through the agency of the atmosphere, a rotary force exactly balancing the retarding energy which we have established.

The advocates of the theory of compensation, while admitting that they cannot furnish any *practical* evidence of the truth of their doctrine, assert that the subject is not susceptible of experimental test. It would, indeed, be a fruitless task to undertake the construction of anemometers, or similar instruments, showing that the pressure and friction of the particles of the returning vapor exerted directly or through atmospheric intervention against the surface of the Mississippi river basin, from west to east, are capable of compensating the established retardation of 19,336,000,000 foot-pounds per second.

The admitted impossibility of proving by direct measurement the existence of compensating force, has suggested the resort to some indirect method. I have accordingly constructed an instrument which, practically, demonstrates the truth of the following proposition, on which the solution of the problem unquestionably depends. The retarding influence produced by currents of *water*, confined within channels which convey a given weight in a given time, from the pole to the equator of a rotating sphere, cannot be counteracted, or compensated, by opposite currents of *vapor* transferring an equal weight, in equal time over the surface of the said sphere from its equator to its pole.

The frontispiece represents the instrument adverted to; but before entering on a description, it will be well to define clearly the problem intended to be solved by experimental demonstration. The rotary velocity of the surface of the earth, for instance on the 45th parallel, is 1,074 ft. per second, that of the equator 1,519 ft. per second; hence the water of a river flowing from lat. 45 deg. to the equator, will have its velocity round the axis of the earth increased 1,519—1,074 =445 ft. per second. It needs no demonstration to show that the expenditure of energy necessary to produce this increase of rotary velocity will cause the earth to rotate at a diminished rate; the amount of retarding force being readily ascertained by multiplying the weight of water transferred, by the height necessary to generate a velocity of 445 ft. per second, viz., 3,094 ft. Consequently, each pound of water transferred from lat. 45 deg. to the equator, demands the expenditure of a dynamic energy of 3,094 foot-pounds. The question now presents itself, whether a pound of water evaporated on the equator, and returned in the form of vapor to lat. 45 deg., can during the return movement impart a rotary energy of 3,094 foot-pounds to the earth. Of course the vapor, on leaving the equator, possesses a rotary velocity of 1,519 ft. per second, while the surface of the earth in lat. 45 deg. rotates, as before stated, at a rate of only 1,074 ft. per second. It will be evident, therefore, that during the return movement the vapor, by contact with the earth, will have its rotary velocity diminished in the ratio of 1,519 : 1,074. On purely theoretical considerations, it must be admitted that this contact, by which the returning pound of *vapor* has its rotary velocity diminished 445 ft. per second, will restore to the earth the whole of the energy which was previously expended in augmenting the speed of the pound of *water* from 1,074 to 1,519 ft. per second during its transfer from lat. 45 deg. to the equator. But practice shows that rotary motion cannot be imparted to cylindrical or spherical bodies, however rough their surface may be, by currents

of air or steam, without great loss of mechanical energy. Conversely, currents of air or steam cannot be produced by the action of similar rotating bodies, without a corresponding loss of mechanical energy.

Practical engineers, familiar with these facts, fully appreciate the difficulty of instituting experiments intended to determine exactly what amount of force is expended in causing rotary motion by currents, and what amount of force is developed by currents produced by rotating bodies, as supposed. The illustrated dynamic register obviates this difficult comparison between energy expended and developed, by the simple expedient of applying heat and cold in such a manner that the *retarding* influence of a current of *water* flowing from the pole to the equator, acts simultaneously with the *accelerating* influence of an opposite current of *vapor*, transferring equal weight in equal time, from the equator towards the pole. The detail of the instrument will be understood by the following description. Fig. 1 shows a section of a hollow sphere 6.25 in. diameter, composed of brass of very light substance, made to revolve on its vertical axis; the upper half being covered with a light semi-spherical casing extending a short distance below the horizontal central plane of the sphere. A cylindrical cistern, provided with a flat cover, is attached to the top of the semi-spherical casing. The mode of supporting the lower pivot on which the sphere turns, as also the axle at the top, will be seen by reference to the drawing. Rotary motion is imparted to the sphere by a horizontal toothed rack (see top view, Fig. 2) working into the teeth of a wheel attached to the vertical axle; the motive power consisting of a weight suspended by a light cord passing over a pulley and secured to the rack. A circular gas pipe, provided with a series of burners, surrounds the sphere some distance below its centre. Referring to Fig. 2, it will be seen that the guide-pieces which support the horizontal rack and through which it slides, act as stops which regulate the the extent of the movement. It should be particularly noticed that the arrangement is such that when the motion is checked by the right-hand stop, the last cog of the rack has just slipped out of the cog-wheel, thus allowing the sphere to turn freely. The extent of motion of the rack is 0.186 ft., and the weight exactly 2 lbs.; it will be seen, therefore, that the motive force is 0.186 by 2 = 0.372 foot-pound or 2 by 7,000 by 0.186 = 2,604 foot-grains. Deducting the loss by friction, 64 foot-grains, the effective motive power will be 2,540 foot-grains. The axis of the sphere being exactly vertical, there is obviously no friction whatever at the upper bearing after the slipping of the last cog, of the rack, while the lower pivot presents a mere point of hardened steel to the step under it; hence the overcoming the atmospheric resistance against the outside of the sphere and the cistern, may be considered as the only work to be performed by the stated available motive power of 2,540 foot-grains. It only remains to be noticed that when the sphere is to be put in motion, the rack is geared into the cog-wheel and brought up against the left-hand stop, as represented in the drawing, the check lever, Fig. 3, being at the same time placed in the position shown by the dotted lines. The moment for starting, indicated by the chronometer, having arrived, the check lever is brought to the horizontal position as quickly as possible in order to prevent dragging at the moment of liberating the toothed rack. As shown by the illustration, a small quantity of water is confined within the surrounding casing of the sphere, thus forming an aqueous belt round its equator; the polar cistern being filled with water.

The object of the instrument having been clearly set forth, it scarcely needs explanation that the device is intended to show that when the heat of the gas flames is applied to the aqueous belt causing evaporation, while condensation is effected by the cold water in the polar cistern, the motive energy (2,540 foot-grains) will be incapable of turning the sphere as fast, and as long, as when heat and refrigeration are not applied. This assumption, it will be perceived, is in direct opposition to the views held by the Astronomer Royal at Stockholm and other followers of Laplace, who contend that "no difference can exist" as regards the effect on the axial rotation of the globe between currents of water and currents of aëriform matter transferring equal weight in equal time.

The mode of conducting the experiment with the dynamic register will be readily understood by the following explanation. The polar cistern is charged with boiling water and the gas flames applied for a few minutes until the water round the equator is brought near boiling heat The gas is then shut off, and the toothed rack geared, and afterwards locked by the check lever. The chronometer being then carefully observed, the lever should be quickly pushed down when the hand marks exact time. The motive weight, being thus liberated, puts the sphere in motion through the intervention of the rack and cog-wheel, the time elapsing between the commencement of the movement and the slipping of the last tooth of the rack occupying about one second. The observation of the chronometer should continue in order to ascertain the exact time when the sphere is brought to rest. In the mean time the number of turns must be accurately counted. The first experiment being concluded, the sphere is again put in motion, as before, without changing the water in the polar cistern or applying the gas flames, the object of employing heat before starting being merely that of expanding the sphere to proper dimensions. The experiment having been repeated 6 times, the *mean* of time occupied, and number of turns performed, resulting from the expended energy of 2,540 foot-grains should be determined with the utmost precision. The procedure will then be changed; the polar cistern will be charged with *cold* water and the gas flames applied and kept burning. The sphere, under these altered conditions, is again started, but not until boiling temperature in the equatorial belt has been attained, and evaporation commenced. The experiment, as before, will be repeated 6 times, and the mean of time and the number of turns ascertained.

The law of compensation relating to solar influence on the axial rotation of the earth, expounded by Dr. Mayer, is evidently strictly applicable to the dynamic register since the equatorial belt of the rotating sphere is being continually heated while the polar region is being exposed to continuous refrigeration, vapor being thus formed at the equator, and currents produced which condense on reaching the cold semi-spherical covering over the pole. The water thus formed, divided into small streams, flows back on the surface of the sphere to the equator, where it is again converted into vapor; hence a continued circulation of opposite currents of vapor and water will be kept up. It should be particularly observed that the vapor in its passage towards the pole, not only acts against the surface of the sphere, but also against the inside of the semi-spherical covering, thereby affording a double chance of imparting motion to the rotating mass. But, this notwithstanding the experiments have shown that the *retarding* energy of the condensed water flowing in small streams from the pole to the equator on the surface of the sphere, greatly exceeds the *accelerating* energy imparted by the excess of rotary velocity of the vapor in its course towards the pole, and the consequent friction of its particles against the surfaces of the sphere and the semi-spherical casing. Agreeable to Dr. Mayer's conclusions, founded on the theory of Laplace, the opposite currents which result from high temperature on the equator, and the refrigeration over the temperate zone and the poles, cannot affect the axial rotation of the globe. "The effect of every single motion by these means on the rotation of the globe," he says, "is exactly compensated by the effect of another motion in an opposite direction." Nor can the Swedish Astronomer, as we have seen, perceive any difference between currents of water and currents of aëriform matter. In direct opposition to the conclusions of these savans, our experiments prove that, although the weight transferred from the pole to the equator of the sphere of the dynamic register is precisely the same as the weight which is transferred in the opposite direction, the contact and friction of the particles of vapor against the surfaces of the convex and concave spheres, is incapable of restoring the loss of *vis viva* consequent on imparting rotary motion to the particles of water transferred from the pole to the equator.

Our space not admitting of a detailed account of the experiments which have been made with the dynamic register, a few important facts only will be noticed in this article. The number of turns of the rotating sphere produced by the

motive force of 2,540 foot-grains, has been 660.5 occupying 10 min. 37 sec., the barometer at the time indicating 29.8, the temperature of the surrounding atmosphere being 62 deg. The mean of the force expended for each turn will therefore amount to $\frac{2540}{660.5} = 3.84$ foot-grains. It will be asked in view of this insignificant motive power, chiefly expended in overcoming the atmospheric resistance against the rotating sphere and cistern, how the excess of retarding energy of the condensed water flowing from the pole to the equator, can possibly be measured. The answer is, that we need not consider the amount of energy developed by the motive weight; we merely count the number of turns, and note the time required to bring the sphere to a state of rest from the moment of starting, the gas flames being kept burning and the refrigerating medium retained in the polar cistern during the observations. Then removing the cooling medium and replacing the same with boiling water, we again put the sphere in motion, count the number of turns and note the time. The result of this change of procedure will be, as shown by our experiments, that the sphere will run much longer and perform a greater number of turns—a startling fact, since the motive energy of 2,540 foot-grains has not been increased. To practical minds the explanation will at once suggest itself, that because there is an *expenditure of heat* while condensation is kept up, which ceases when the refrigerating medium is withdrawn, some additional work is being performed while the cold medium remains at the pole. Now, what is the nature of this work? Evidently the condensed water while flowing from the pole to the equator has its rotary speed successively increased corresponding with that of the surface of the sphere; hence work must be performed while refrigeration is kept up at the pole. Satisfactory as this explanation appears, it is met by the cardinal objection, that since force cannot be annihilated, the opposite current of *vapor* which simultaneously transfers an equal weight from the equator to the pole of the rotating sphere, must, by friction or contact of some kind, positively return the whole of the mechanical energy expended in augmenting the rotary velocity of the particles of water moving in a contrary direction. This, notwithstanding, we must accept the *fact* proved by the dynamic register, that a certain amount of mechanical energy *disappears* when the rotating sphere is subjected to the action of differential temperatures. There was a time when we could not account for such disappearance of energy, but—thanks to the labors of Joule and Mayer—the mechanical theory of heat has thrown light on the subject. The theoretical deductions of Laplace have lost their potency. We no longer confine ourselves to the balance and rule in measuring the result of expended force. Joule and Mayer have taught us to consult also the *thermometer* during our investigations. Bearing in mind, then, what the new theory of heat teaches, the disappearance of mechanical energy during the experiments with the dynamic register, ceases to be a puzzle. Close investigation shows that the heat resulting from the arrested motion of the circulating vapor, which, on leaving the aqueous belt, possesses a rotary velocity equal with that of the circumference of the sphere, represents very nearly an equivalent of the observed loss of energy; the difference being made up by heat generated by the particles of the circulating vapor as they successively impinge against the minute projections of the surface of the convex and concave spheres. Obviously the heat thus generated is carried off by the cold semi-spherical casing surrounding the sphere of the dynamic register, precisely as heat produced by analogous motions within the terrestrial atmosphere is carried off by radiation into space. In either case, the heat lost is an exact equivalent of the mechanical energy abstracted from the rotating sphere.

George H. Stem & Co., of Stemton, Northampton county, Pa., employ 160 men in their car works, have three full sets of machinery, and are able to turn out twelve 6-ton coal cars per day by working overtime.

It is stated that in European Russia there are 19.266,667 horses, or 260 for every 1,000 men.

THE WORKING EXPENSES OF STEAMERS OF SMALL SIZE.

By A. F. YARROW, Esq.

From the "Journal of the Society of Arts."

Steam launches have for several years been extensively adopted in Norway and Sweden, carrying on there successfully the traffic across the many estuaries and fiords formed by a very irregular coast line. It is, however, only within a comparatively recent period that these little craft have become generally known in this country. To identify more particularly the type of boat I am now referring to, I may mention that they vary from 30 ft. to 60 ft. in length, and from 6 ft. to 12 ft. in beam, generally have no neck, and are propelled mostly by one, but occasionally by two screws, driven by high-pressure direct-acting engines.

One of the first successful attempts made in this country to develop passenger traffic by boats of this type was started at Plymouth, in 1869.

A small company was formed, called the Oreston Steamboat Company, with a view to run between Plymouth and Oreston, calling at Hooe, Turnchapel, and Mount Batten, the only communication at the time being by watermen's boats, or a three-mile walk and a toll of one penny.

The first steamer purchased was called the Little Pet. It was 40 ft. in length by 7 ft. 6 in. beam. The success of this boat induced the company to order another (which was called the Favorite), 50 ft. in length by 10 ft. beam, driven by a pair of $5\frac{1}{2}$ inch. cylinders, and licensed by the Board of Trade to carry 84 persons. The average time occupied by this boat in the run of $1\frac{3}{4}$ miles, was fifteen minutes, including stoppages, and the fare charged 1d.

There was no deck whatever, but a cabin, the full width of the boat, and 10 ft. in length, was provided aft. The draught of water, when at work, was 3 ft., with a speed, over a straight course, of 8 to 9 miles an hour.

To show more clearly the exact nature of the traffic carried on, I beg your reference to the rough map of Plymouth. At the Barbican-pier the boats run alongside the quay, and at Oreston there is a small jetty; but at Hooe, Turnchapel, and Mount Batten the boats are generally run on to the beach, and a plank thrown out forward for the outgoing and incoming passengers. This simple means appears to answer the requirements of the case, and the boats, which are strongly built of wood, and suitably shaped to take the ground, do not materially suffer.

A considerable business is done in taking off and putting on board passengers from the vessels lying at the anchorage in the Catwater; and, if hailed from the shore, the boats are frequently beached to take people up.

Gained from the experience of this company, the cost of working such a launch as the Favorite, running 24 journeys per day of 12 hours, each journey being $1\frac{3}{4}$ miles, it has been found that the consumption of fuel has been 8 cwt. per day, and the consumption of fresh water 350 gallons per day. I may here mention that water tanks are fitted to this boat sufficient for 4 hours' constant steaming, these tanks being replenished from time to time by the hose at the quay.

The crew consists of a captain, receiving 24s. per week, engine-driver, 21s. per per week, and a collector, 18s. per week.

These and other expenses I have tabulated, the total working expenses per week being £8 12s. 11d.

This company has attained considerable success; the credit for which is mainly due to Mr. Edmund Jones, a resident of Plymouth, who writes as follows:

"During the past summer, each of the three boats has earned occasionally as much as £20 per week, and the opposition company, who have also three boats, nearly as much. The cost of repairs, however, is very heavy; the watermen, who show a most determined hatred to the boats, do much injury; and for a long time we had always to keep a watchman on board to guard against malicious damage; and what with racing with the opposition, and consequent coal-wasting, lawsuits, summonses from the watermen whenever we by chance carried over our legal number, we have had a tough lot of battling, gaining, by paying dearly, valuable experience. During the last dry summer the fresh water supply ran short, which caused much injury to the boilers

from want of sufficient care in constantly blowing off, to prevent incrustation when feeding from the sea. The boats, however, after paying for all this, as well as putting by towards renewal fund, have given a very good profit."

We will now just glance at quite a different style of steamer, one which I have specially selected as doubtless familiar to us all—I refer to those running on the Thames between London and Westminster bridges and intermediate piers.

They average 110 ft. in length by 14 ft. beam, being certified to carry 370 passengers, and are propelled by condensing paddle engines of 24 horse-power nominal.

To give some idea of the cost of working such a steamer, I have tabulated the expenses at £29 4s. 9d. per week.

These boats are of a type doubtless well designed and ably managed, but I contend that they are unsuited for the work to be performed. Boats of smaller size, such for example as the one I have briefly described, would, in my opinion, fulfil the requirements of the case much better. They could be more numerous, leaving the piers more frequently; they would be much more easily handled and brought up alongside the landing stages; a very much smaller original outlay would be requisite, as well as greatly reduced working expenses. I will admit that during certain hours of the day in fine weather in the summer months, the present steamers will have their full complement of passengers; but it is clearly an error to entail excessive working expenses during the whole year, for the sake of rendering available the maximum traffic during a very limited period.

When running in fresh water, on lakes or rivers, the extreme simplicity of the ordinary type of steam launch enables it to be worked with perfect safety and success, by any one of moderate intelligence and care; but when used at sea, where salt water only can be obtained for the supply of the boiler, the difficulties are greatly augmented, owing to the risk entailed from incrustation and eventual destruction of the boiler. Whatever care may be requisite on board ocean steamers worked by competent men, even still greater care is required with high-pressure engines, the boilers adopted as a rule having much greater evaporative power in proportion to their contents.

With the aid of the salinometer, the amount of brine requisite to be blown off to prevent salting up can be carefully regulated, and the boiler preserved for many years in perfectly good condition. This, however, requires an amount of care and attention which experience has proved to be most difficult to obtain even in this country; and abroad, in places where skilled labor is scarce, it is sometimes simply impossible. In all cases where a supply of fresh water can be procured on shore, it is unquestionably desirable to have tanks fitted on board from which to feed the boiler, and if these tanks hold sufficient to last until they can be replenished, the boat can be worked without any special care. The use of the ordinary surface condenser is one mode of obtaining a supply of fresh water; but the great complication of such means is a serious barrier to its adoption, sacrificing at once the marked feature of the steam launch, which is its simplicity, in addition to increasing the cost, and depriving the boiler of the benefit of the blast up the chimney.

It has frequently been proposed, and even tried, to condense the steam by passing the exhaust pipe along the outside of the boat, the external surface coming in contact with the water, and thereby condensing the steam within. I am not aware of any trials of this kind which have proved successful until the middle of last year, when Mr. Alexander Crichton, of Cork, fitted two Government steam launches with such apparatus. These launches were of the well-known twin-screw type, having two cylinders to each screw secured to the sides of locomotive boilers. The exhaust pipes were passed through the boat's bottom, and carried alongside the keel for 14 ft., and then returning 16 ft. re-entered the boat, and were at once connected to two small air-pumps worked by eccentrics. These air-pumps delivered into a hot well, to which the suction of the feed pumps was attached. Under these circumstances the whole of the exhaust steam was condensed and returned to the boiler as fresh water, the only loss worthy of notice being that due to the steam-jet, which had to be kept going in the funnel to

maintain the requisite draft. In both these launches there appeared to be a considerable gain both in power indicated as well as in speed. The capacity of the air-pumps, which were single acting, was 1-20th the capacity of the cylinders. There can be no possible doubt that if these results can be confirmed over a lengthened period, that they are indeed most valuable, and great credit is due to Mr. Crichton.

We ourselves last month tried some experiments in the same direction, with a small wooden tug boat we have just completed for the Brazils, in which it was a most essential point to carry water and fuel for as many hours as possible.

The boat was 37 ft. in length, 9 ft. in beam, and 5 ft. in depth. The engine consisted of a single cylinder, 9½-in. diameter by 12-in. stroke, and the boiler of the usual return tube type. As the boat was small for the weight of machinery, there was not buoyancy left sufficient to carry the desired quantity of fresh water. We therefore considered this a specially favorable instance for testing the merits of this system. All we were anxious to do was to secure the return of the bulk of the water to the boiler, at the same time retaining amply sufficient blast.

The exhaust pipe was passed to the forward end of the boat, terminating in a breeches-piece, which went through the skin on each side of the keel. To this were secured two 3-in. copper pipes, each 21 ft. long, running along the boat's bottom towards the stern. At the after end of these pipes was attached another breeches-piece, which re-entered the boat, and was connected to the suction of a small plunger pump 1¾-in. diameter by 6-in. stroke, worked by an eccentric from the screw shaft, as shown. This pump delivered into tanks placed on each side the boat. The inclination of the condensing tubes, when the boat was running, was about $\frac{5}{8}$ of an inch to the foot.

We provided means for conducting the exhaust either wholly up the chimney or partially into the chimney and partially into the condensing tubes, always retaining ample collective area for the steam to pass through, which was never less than equal to an orifice of 2¼ in. diameter.

Over a lengthened trial the following were the results obtained, which I have tabulated on sheet 6: Consumption of midland coal per hour, 120 lbs.; evaporation of water, 780 lbs.; pressure of steam per sq. in., 54 lbs.; estimated indicated horse-power, 20½; revolutions per minute, 120.

Under these circumstances, we found three-fourths of the steam could be condensed without apparently injuring the draft, the remaining one-fourth passing up the funnel: The exact quantity of water delivered back into the tanks was, per hour, 580 lbs.; the temperature of the water in the river being 44 deg.; the temperature of water pumped from condensing tubes, 59 deg.

The following will be the practical bearings of these results, which are tabulated on sheet 7: Presuming the tanks and boiler to be filled with fresh water, and worked in the ordinary way, the tanks, which contain 320 gallons, will be emptied after 4 hours' steaming. If the condensing apparatus be at work they will be emptied after 16 hours' steaming.

We will now assume that, after the expiration of these times, we are forced from necessity to pump from the sea, and we will also assume that the water in the boiler must never have in solution more than $\frac{3}{33}$ its weight of salt, and that up to that time there is no fear of incrustation.

The boiler contains about one ton of water, and as the sea holds in solution $\frac{1}{33}$ its weight of salt, it is clear that 3 tons of water must be evaporated and replaced by 3 tons of sea-water before $\frac{3}{33}$ of salt will be present in the boiler. This would occupy in the ordinary way 8½ hours additional. If with condensing apparatus at work, 34 hours additional. We therefore finally arrive at the fact, that the total length of time the boiler can be worked with perfect safety from first starting, without risk of incrustation, will be: With fresh water tanks only, 12½ hours; if with condensing apparatus, 50 hours.

For the sake of comparison I have added the time that it would require, if salt water only were used for the boiler, for it to arrive at the same degree of saturation; this could be attained after the evaporation of 2 tons of water, which would occupy 5¾ hours.

I will make no remark on these figures; the practical results are clear without further comment.

The boat upon which these experi-

ments were tried was of wood, but had it been of iron the condensation of the exhaust steam would have been even more readily effected, the condensing pipes would have been quite unnecessary, the skin of the boat itself serving equally well as the conducting medium. To illustrate one practical method of carrying this out, I beg your reference to sheet 8. That portion of the exhaust to be condensed would be passed into a receiver, of which the skin of the boat would form its external side; assuming the frames of the boats to be 18 in. apart, ample area would be obtained if the space between three frames be taken, and from the water level on the one side to the water level on the other, this would not only form a suitable reservoir for receiving and condensing the steam, but would give additional stiffness to the hull at the very place required, as well as serve as a substantial platform for the engine. The feed-pump could take its suction, as shown, and force direct into the boiler, no additional pump being required.

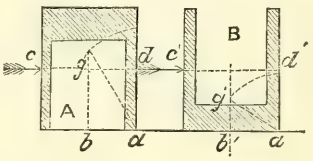
As to whether this plan is capable of extensive adoption (which I firmly believe), it is not for me now to enter; but it is certain the required end is obtained at a nominal cost, and without additional complication.

THE STABILITY OF ROLLING STOCK.

From "Engineering."

In the course of recent articles on narrow-gauge railways and their rolling stock we have, on several occasions, spoken in general terms of the lateral stability of such stock, and promised that we should take an early opportunity of considering the subject in greater detail. This promise we now propose to fulfil, and we cannot perhaps do better than commence by explaining exactly what we mean by "lateral stability." The "lateral stability" of a railway vehicle is of two kinds; first, its statical stability or its resistance when in a state of rest, to be upset by a steadily applied lateral force; and second, its stability—or to use a more expressive term, perhaps, its steadiness—when in motion, or its power to resist the setting up of lateral oscillations by the inequalities of the road. The statical stability of any vehicle of a given weight and placed on a line of given gauge, of which the rails are at the same level, is unaffected by the width of that vehicle or the height of its centre of gravity above the rails, while it is influenced, in most cases which occur in practice, in but a moderate degree by the flexibility of the springs and their position. On the other hand, the stability while in motion—or, as we shall term it for the sake of distinction, the "steadiness"—of a vehicle is considerably affected by the height of the centre of gravity above the rails, by the width of the vehicle and the lateral distribution of the weights, and by the flexibility of the springs and their arrangement, while it is influenced to a very important extent by the state of the line, and the speed at which the latter is traversed by the vehicle. We shall in the present article consider the statical stability of rolling stock only, leaving the question of the "steadiness" when in motion, to be considered on a future occasion, and we shall confine our attention solely to the resistances

FIG. 1



to forces acting laterally, as being those principally affected by the width of the gauge on which a vehicle runs.

In the case of a vehicle not mounted on springs, and of which the weight is known, the determination of the statical stability is an exceedingly simple matter. In such a case the stability is, as we have stated, independent of the height of the centre of gravity above the rail level, and depends simply upon the weight of the vehicle and width of gauge of the line on which it is situated. That this is the case will readily be understood on a reference to Fig. 1. In this figure a body of ⊔ section is represented in two positions, A

and B, the body being in each case supposed to be acted upon by a force applied in the direction of the arrow, and tending to produce the overturning of the body on the corners, a and a', respectively. In the case of the position A, the centre of gravity is situated at the height, $g\ b$, above the base line, while in the case of B, its height above that line is but $g'\ b'$, or about half as much as in the former instance, but it is evident that this in no way affects the resistance to the overturning force. In each case that force acts, as it were, at the end of the arm of a lever of the length, $a\ d = a'\ d'$, and in each case the righting moment opposed in this force is equal to the weight of the body acting at the end of the arm of a lever of the length, $a\ b = a'\ b'$. The moments of the overturning force and the righting moments are thus the same in the two cases, and the height of the centre of gravity above the base has therefore no influence upon the statical stability of the body.

We have explained this matter at a greater length than it, from its elementary character, perhaps deserves, because we have noted that some railway engineers appear to imagine that the resistance of a railway vehicle to being overturned by the wind is influenced by the height of the centre of gravity above the rail level, whereas this height has practically, as we have shown, nothing whatever to do with the matter, so long as the vehicle is standing on a portion of the line having the rails on the same level. The manner in which inequalities in the levels of the rails affect the stability we shall show presently. It is true that the lower the centre of gravity the greater is the angle through which the vehicle has to be canted before there ceases to be any righting moment; but this fact is of no practical value as far as the statical stability is concerned, as with all positions of the centre of gravity occurring in practice the righting moment decreases as the vehicle is canted over in a much more rapid ratio than the effective pressure of the wind is diminished by the inclination of the surface on which it acts, and thus the power to resist any given wind pressure decreases as the canting proceeds.

In case of a railway vehicle with wheels in good condition, standing on a well laid line, the points of contact of the wheels and rails are generally situated at about the middle of the width of the latter, and the breadth of base to be taken in calculations, referring to the lateral stability, may therefore in such instances be assumed to be equal to the distance between the rail centres. Inasmuch, however, as from the wear of the tyres, or the canting of the rails in bad portions of a road, the points of contact between the wheels and rails may be shifted to near the inner edges of the latter, it is safer in calculations of the kind to which we are referring, to assume the breadth of base to be equal to the width of the gauge; and it is this breadth of base which we have taken in all our calculations.

The actual width of base may in fact vary in practice to the extent of about twice the width of the heads of the rails, and, in the case of lines of very narrow gauge, this variation will occasion an important percentage of variation in the resistance of vehicles to forces tending to cant them laterally; while the wider the gauge the less will be the proportionate alteration in the stability due to the shifting of the points of contact between the wheels and rails from the outer to the inner edges of the latter, or *vice versa*. It will thus be seen that in the case of very narrow gauge lines, it is important that the width of base should be taken as equal to the gauge only, if it is desired to obtain results which are reliable under all circumstances.

In the case of the force tending to produce overturning being that due to the pressure of the wind, this pressure may be considered to be all concentrated at the point representing the centre of gravity of the exposed side area, and for convenience we shall term this point the centre of pressure. To obtain the total pressure of wind required to just balance the righting moment of the vehicle, we have thus only to multiply the weight of the vehicle in pounds by the half width of the gauge, and to divide the product by the height of the centre of pressure above rail level. Of course the half-width of the gauge and the height of the centre of pressure above the rail must be expressed in the same unit of measurement. Dividing the total pressure obtained, as above, by the side area in sq. ft., we get the required pres-

sure of wind per sq. ft. Expressed algebraically the rules become :

$$(1.) \quad . \quad . \quad . \quad P = \frac{W\,b}{H}.$$

$$(2.) \quad . \quad . \quad . \quad p = \frac{P}{a} \text{ or } = \frac{W\,b}{H\,a}$$

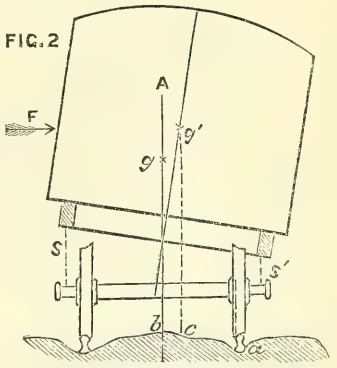
in which formulæ, P = the total lateral pressure; p = the pressure per sq. ft. on the side area; H = the height of the centre of pressure above the rails; b = the half breadth of the gauge expressed in the same unit of measurement as h ; and a = the exposed side area in sq. ft. It has been sometimes urged as an excuse for proposing the use of vehicles possessing an insufficient resistance to the lateral pressure of the wind, that the direction of the latter is but rarely directly at right angles with the side of the carriage and that, therefore, the effective pressure is reduced. It is quite true that the effective pressure exerted by a wind of any given force varies directly as the sine of the angle enclosed between its line of direction and the plane of the surface on which it impinges; but those who urge the argument above referred to appear to forget that the sine of the angle just mentioned decreases but very slowly for the the first 20 deg. or so from a right angle. Thus on referring to a table of natural sines it will be seen that the effective pressure exerted by any given wind upon the side of a vehicle will vary as follows, according to the angle which its direction forms with the surface on which it strikes :

Angle enclosed between line of direction of wind and the side of the vehicle. deg.	Effective pressure of wind given in percentages of the pressure which would have been exerted by it if its line of direction had been at right angles to the side of the vehicle. per cent.
80	98.48
70	93 97
60	86 6
50	76.6
40	64.28
30	50.00

It will be seen from the above table that the deviation of the direction of the wind to the extent of 10 deg. from the perpendicular decreases the effective pressure but about 1½ per cent., while it is not until that deviation becomes as great as 60 deg. that the effective pressure exerted is reduced one-half.

We have now to consider the extent to which the general deductions above arrived at are modified by the fact of a vehicle being mounted on springs. In the first place, the springs may be considered to divide the vehicle into two parts, the upper one of which, or that situated above a plane passing through the points of bearing of the springs, may be canted to a certain extent without affecting the part situated below that plane. Fig. 2, which represents in an exaggerated degree the action to which we refer, will explain our meaning clearly.

FIG. 2



An examination of this figure will show that when a vehicle mounted on springs is subjected to a lateral pressure exerted against the side of the body, either the body may be canted on the springs or the whole vehicle may be canted together on one of the rails as a turning point; and which of these actions will take place depends upon the following considerations: The moment of the force tending to produce a canting of the upper part of the vehicle upon the springs is equal to the pressure exerted against the side surface multiplied by the height of the centre of pressure above the plane passing through the bearing points of the springs ; whilst the moment of resistance to this force would, if it were not for the elasticity of the springs, be equal to the weight of that part of the vehicle resting on the springs multiplied by the half distance between the spring centres. Thus if s = the half distance between the springs ; w = the weight of that portion of the vehicle carried on the springs; and h = the height of the centre of pressure above the plane passing through the bearing points of the springs; then the force F, required to produce a canting of the upper part of the vehicle on the springs would, if it were

not for the elasticity of the latter, be given by the following simple formula:

(3.) . . . $F = \frac{w\,s}{h}$.

On the other hand, the pressure, P, required to cause the whole vehicle to be canted on one of the rails, is given by formula (1) and under the circumstances we have supposed, it would evidently depend upon whether P was greater or less than F, whether the upper part of the vehicle would be canted on the springs, or the whole vehicle on the rails, under the action of a lateral force. In the case of vehicles mounted on very rigid springs spread at a good distance apart, the formula just given may be used without incurring any error of practical importance; but if the springs be very flexible—deflecting, say 2 in. or 3 in. per ton of load, or if their distance apart be small, it may be necessary to take into consideration the manner in which the elasticity of the springs affects the stability of the vehicles. Theoretically it is correct that the influence of this elasticity should be taken into consideration in all cases, but practically—with the proportions of rolling stock ordinarily met with—the influence of this elasticity on the statical stability of a vehicle is so small that it may in the majority of instances, in the case of rolling stock for broad gauge lines, be neglected altogether. In the case of narrow gauge stock the influence of the elasticity of the springs is more important as the following example will show.

Let us, for instance, suppose the case of a four-wheeled carriage on a line of 3 ft. gauge, this carriage having a side surface of 150 sq. ft. and being exposed to a wind pressure equal to 10 lbs. per sq. ft. Let this carriage be mounted on springs deflecting 1 in. for each 750 lbs. of load, and placed at a distance of 4 ft. 8 in. apart from centre to centre (the half-width, s, being thus 28 in.), and let the height of the centre of pressure above the plane passing through the bearing points of the springs be 3 ft. 6 in. Finally, let the centre of gravity of that part of the vehicle mounted on the springs be situated 2 ft. 8 in. above the plane just mentioned.

The pressure of the wind will cause an increase in the load on the springs on the lee side of the carriage and a corresponding decrease of load on those on the opposite side; the *difference of load* on the two sides, amounting under the circumstances above supposed to $\frac{150\times10\times42}{28} = 2{,}250$ lbs. In other words, the load on the 2 springs on the lee side will be increased 1,125 lbs. or 562½ lbs. per spring, and the load on those on the opposite side decreased to an equal amount. The elasticity of the springs being such that they each deflect 1 in. under a load of 750 lbs., the inequality of load above mentioned will result in an additional deflection of ¾ in. in the springs on the lee side and a rise or decrease of deflection of an equal amount in the springs on the other side, the upper part of the carriage being thus canted to an extent measured by a difference of 1½ in. in the level of the bearing points of the springs on the opposite sides. Multiplying now this 1½ in. by 2 ft. 8 in. and dividing this product by 2 ft. 4 in., we get $\frac{1.5\times32}{28} = 1.714$ in. as the amount to which the centre of gravity of that part of the vehicle carried by the springs has been shifted laterally by the unequal deflection of the springs on the two sides.* Referring now to Fig. 2, we may suppose g' in that fig. to represent the altered position of the centre of gravity of that part of the vehicle carried by the springs, and it will be seen that the resistance offered by the weight of that portion to the overturning of the vehicle on the point a, is diminished by the canting on the springs in the proportion of $a\,c$ to $a\,b$. But we have shown that $b\,c = 1.714$ in. and as $a\,b$ = half the width of the gauge = 18 in., that part of the resistance to overturning due to the weight of the spring-carried portion of the vehicle has been diminished in the proportion of 16.286 to 18, or about 10½ per cent.

If now the weight of that portion of the vehicle carried by the springs amounts to ¾ths of the total weight, we shall have the stability of the vehicle, considered as a whole, diminished to the extent of

$$\frac{10.5\times3}{4} = 7.875$$

per cent. by the canting of the upper part of the springs.

We have supposed, in the above example,

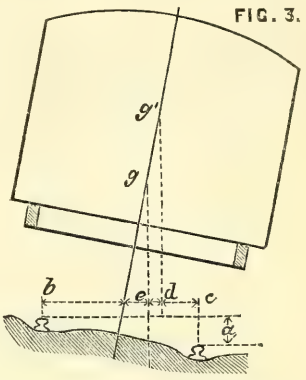
* In reality, this shifting of the centre of gravity laterally would of itself throw an extra load on the springs on the lee side, and thus cause their additional deflection. To avoid complication, however, we have neglected this small increment of deflection.

that by the time the upper part of the vehicle was canted to the extent stated, the difference in the pressures on the springs, s and s' (see Fig. 2), was sufficient to cause the canting, on the point a, of those parts of the carriage below the spring. It is probable, however, that, with the proportions of parts ordinarily met with in practice, this difference of pressure would *not* be sufficient to produce the result supposed, and, under these circumstances, an increased lateral pressure would be required to produce the overturning of the vehicle, and this increased lateral pressure would be attended with an increased canting of the upper part of the vehicle on its springs, and consequently a further reduction of its stability.

A consideration of the facts above stated leads to three important practical deductions. The first of these is, that the higher the centre of gravity of the spring-carried portion of the vehicle is above the plane passing through the bearing points of the springs, the greater is the reduction of the stability due to canting of the upper portion of the vehicle in the manner represented in Fig. 2; while the second deduction is that it is extremely important to give to narrow-gauge rolling stock as wide a spring base as possible, and to regulate the flexibility of the springs according to the width of spring base attainable. The third deduction is that in the case of vehicles carried on bearings situated inside the wheels, the resistance to the overturning of the upper part of the vehicle on the springs is always less than that opposed to the overturning of the whole vehicle on the rails; and consequently that in order that the latter event may take place, it is necessary that the springs should be actually coupled to the upper part of the vehicle, and not merely bear against it. Otherwise, the weights of those portions of the vehicle not carried on the springs possess no influence on the stability of the whole.

We now come to the last point which we intend to consider in the present article, and that is the influence of an inequality in the level of the rails, on the stability of a vehicle. Fig. 3 will illustrate the effect of such an inequality. In this figure one rail is represented lower than the other to the extent a; and if we suppose that the centre of gravity of a vehicle standing on this line be situated at g, it will be seen that the righting moment,

FIG. 3.

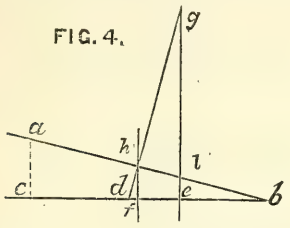


tending to prevent the overturning of the vehicle towards the lower side, will only be equal to the weight multiplied by the distance, $c\ e$; or, in other words, it will be less than the righting moment which exists when the vehicle is standing on a level line, by as much as $c\ e$ is less than half the width of the gauge, $c\ d$. It will also be noticed that whereas when a vehicle is standing on a level line, the height of the centre of gravity exercises no influence on the statical stability of the vehicle, on a line having one rail lower than the other, the position of the centre of gravity is of considerable importance. Thus, in the case shown in Fig. 3, if the centre of gravity of the vehicle was situated at g' instead of g, the righting moment would be reduced in the proportion of $d\ c$ to $e\ c$, the lines $g\ e$ and $g'\ d$ being, we need hardly say, perpendiculars, let fall from the respective centres of gravity, g' and g'.

Very little consideration is required to show that, other things being equal, the effect of any given inequality in the level of the rails upon the stability of a vehicle placed on them will vary directly as the gauge of the line. It will also be seen that the *actual amount* of the reduction in the stability due to any given inequality of level of the rails will be directly proportionate to the height of the centre of gravity of the vehicle above the latter, the *percentage* of the reduction, however, being dependent, not on the height of the centre of gravity alone, but on the proportion between that height and the width of the gauge. For instance, in Fig. 4, let $a\ b$ be a line joining the heads of two

rails, of which one is higher than the other by the amount $a\,c$, and let g represent the position of the centre of gravity of a vehicle standing on such a line. Then g h drawn perpendicular to $a\,b$ represents the height of the centre of gravity above the rail level when the vehicle is standing on a line of which the rails are at an uni-

FIG. 4.



form height, and $g\,e$ is a perpendicular drawn from the point g to the level base line, $c\,b$. In this figure it is evident, from what we have already stated, that if the half breadth of gauge, $h\,b$, be taken as representing the stability of the vehicle when standing on a line having the rails at the same level, then $h\,i$ will represent the amount of reduction of that stability due to the canting of the line to the extent, $a\,c$, and the fraction $\frac{h\,i}{h\,b}$ will represent the *proportionate* reduction of stability thus effected. Moreover, it is evident that $a\,b\,c$ and $g\,h\,i$ are similar triangles, and thus

$$h\,i = \frac{c \times g\,h}{c\,b}. \quad \text{But } c\,b = \sqrt{a\,b^2 - a\,c^2},$$

and substituting this value in the preceding formula, the value of $h\,i$ can readily be calculated whenever the width of gauge, difference of level of the two rails, and height of the centre of gravity of the vehicle above the rail level, are known. For instance, let G = the height of the centre of gravity above the rail level; b =, as before, the half-width of gauge; x = the amount to which one rail is above the level of the other; S = the moment of stability of the vehicle when standing on a line with rails at the same level; R = the moment of stability of the same vehicle when standing on a line having one rail higher than the other by the amount x; and W =, as before, the weight of the vehicle. Then

(4.) . . $S = W\,b$; and

(5.) . . $R = S \dfrac{b - \dfrac{x\,G}{\sqrt{4^2\,b - x^2}}}{b}$.

This formula merely gives the reduced stability due to the unequal level of the rails, and does not take into account any further reduction due to the action of the springs. This further reduction may, however, be readily ascertained in the manner we have already explained. The present article has already reached such a length that we must forbear from saying anything more concerning the stability of rolling stock here; but we intend to return to the subject, and point out the manner in which the width of the gauge and the proportions of the vehicle affect the steadiness of the latter when running over a line having such inequalities as are ordinarily met with in practice.

STEAM FIRE ENGINES FOR JAPAN.—Messrs. Merryweather and Sons have just completed two of their 300 gallon steam fire engines for the Government of Japan. Each engine is fitted with a large quantity of delivery hose and every requisite. On testing them before shipment each raised steam from cold water in 8 min. A steam fire engine of a similar construction, but more powerful, has been forwarded this week to the Marquis of Exeter, Burghley House, Stamford. The engine was tested in the presence of the Marquis and many of the surrounding gentry and nobility, and gave great satisfaction. This engine discharges 450 gals. per min., and raises steam in 8 min. Had such an engine been at Holker, the Duke of Devonshire's seat at Cartmel, we should not have had to record a total loss of one wing of the noble mansion, estimated at £30,000.

THE new furnace of the Leland Lake Superior Iron Co., situated on the Eastern shore of Lake Michigan, opposite Green Bay, was successfully blown in on the 22d ult. The height of the stack is 52 ft.; diameter of bosh, 10 ft. 6 in.; casting house, 70 x 50 ft. The blowing cylinder and machinery are driven by two 65 in. Houston turbine wheels. Ten charcoal kilns, 56 x 18 and 20 ft. high, have been built on the bank of Carp River, which, with the lakes tributary to it, will furnish an inexhaustible supply of hard wood for charcoal. The furnace and kilns have cost about $86,000 and 25 tons of iron can be turned out daily.

SUBURBAN RAILROADS—THEIR CONSTRUCTION AND OPERATION.

By T. McDONOUGH.

At the time when the various lines of railroad leading from New York into the interior were built, the principal object was to accommodate a mixed traffic of freight and passengers, carried over long distances; and the consolidation of lines stretching far westward, with the profit resulting from it, has made the short traffic of comparatively less importance as a source of income, under the present method of managing it. As the short traffic has gradually increased so as to require special trains, these have been merely duplicates of those used for long travel.

In reviewing the methods proposed, as adapted to the requirements of this short traffic, prominence has lately been given to roads of narrow gauge, on account of their financial success in Wales, and also in some parts of the Continent of Europe. It is claimed that these roads are cheaper to build as well as more economical to operate.

The principal saving in cost of building such roads is made up as follows: In the quantities of land required, and of excavation and embankment; in the use of shorter ties; and also the saving in cost of equipment; as such roads require light engines and cars. The saving in construction may be about as follows: When a road has light cuts and fills of not more than 15,000 cubic yards to the mile, there will be about $\frac{1}{6}$ less earth to be moved. But this saving will be rapidly lessened when the cuttings are deeper than 6 ft., the saving being only made in the road bed, which is only a small part of the excavation in deeper cuttings. In these the slopes furnish most of the material. These require the same amount of earth to be removed for a narrow bed as for a wide one, so that with any work, except that under 6 ft. depth of cutting or height of embankment, the saving will be inconsiderable. The ties will be shorter by the difference between a 3 ft. and a 4 ft. $8\frac{1}{2}$ in. gauge, which is the difference between the width of the two systems, the present one and that under consideration.

The above are the principal items in which any saving can be made, for cheap and light cars can be used on either gauge; but those on the present gauge will give more accommodation to passengers. With these slight advantages, there is the serious drawback, that such roads, if they enter upon those now built, will require a third rail to be laid for their use. This objection will have force upon any lines to be laid near the large cities, though there may be exceptional cases where it does not apply. There being no advantages in the 3 ft. gauge sufficient to recommend it in preference to that used at present, the various modes proposed for the accommodation of the short traffic on the present lines will now be considered. That one now adopted to a limited extent, using a car with engine in one end, is adapted to carry about 80 passengers, but is not suited to carry more, and to stop and start, so often as is required; nor can they be reversed at the ends of the route without a turn-table, should it be desired to run the engine always ahead of the passengers. They were not considered suitable for the London Metropolitan line, which is the one that seems to have studied the adaptation of the cars suited to its traffic with care, because they did not supply sufficient power to get up speed as rapidly as required with frequent stops.

As nothing suited to the purpose of conducting the short traffic seems to be in use at present, it may be seen what is required, by an examination of the elements of cost of the present trains in detail. A train to carry 100 passengers consists of the engine and tender of 25 tons, a baggage-car and two long cars, amounting in all to 77 tons, including the weight of 100 passengers, or to 1,550 lbs. for each person carried. The long cars have more than 600 lbs. weight for each person carried.

The attendants, with their wages by the day, are an engineer at $3.48, a fireman at $2.25, a conductor at $3.88, a baggage-man at $2.24, and three brakemen at $5, or a total expense by the day of $17.07. Besides this, the cost by the mile run, is as follows: Fuel, $0.079, oil and grease $0.13, engine repairs, $0.13, car

repairs, \$0.10, being a total expense by the mile of $33\frac{1}{3}$ cents. It will be seen by the above, that the dead weight hauled per passenger is very great, and this requires an unnecessary outlay for attendance, and also for hauling. If the dead weight per passenger can be reduced, a proportionate saving of labor and fuel and oil, can also be made.

With these ends in view, the following plan is now suggested, for local traffic of passengers residing not more than 20 miles from the city, a distance about equivalent to one hour's ride in the horse cars up town.

The cars proposed are to be a compromise between the horse and the rail cars. They are to carry the passengers, seated as now in the long cars, on seats for two at the side of the car, with a middle passage and end doors. With seats $2\frac{1}{2}$ ft. apart, a car will carry 40 passengers, if made 25 ft. long. These cars are to be set on axles with as wide a base as the curvature of the road will permit, with but little overhang at the ends; and should be fastened together by spring couplers so as to have the train move as one mass. In other respects, they would be modelled like the horse cars. These weigh about 2 tons, and carry safely more than twice the number they can seat. By allowing a ton additional for the framing and bracing of the proposed car, it would then weigh 3 tons, for 40 persons. Assuming now that 200 persons are to be carried, 5 cars and their load will weigh 30 tons. The engine for such a weight may be lighted, and not exceed 10 tons. It should be made to run either end foremost so as to make no delay at the end of the route, by going on a turn-table, but merely switch off, and back to its place at the head of the train, in the direction of the next run. Requiring but little fuel and water for its light load, the tank can be put on the engine frame near to the ground. A train made up in this manner will have great stability, the water and passengers being about 2 ft. nearer the ground than at present.

The total weight will be 40 tons, with power and adhesion sufficient to stop and start quickly, and it will move steadily, since the cars are bound tightly together, and they also have a low centre of gravity. With the same expenses per ton moved as those of the train mentioned above, and assuming that 10 trips can be made in 16 hours, the cost of a 20 mile run will be \$1.15 for attendance, and \$3.32 for fuel, oil and repairs, or a total of \$4.47 per trip, with a capacity to carry 125 passengers through the whole length of the trip. Starting from the city with 200 persons, and leaving part of the load at every station, will give that number as the average through 20 miles. The actual cost of carrying 1 passenger 20 miles will be $3\frac{4}{10}$ cents for train expenses. This is rather less than the rate at which it is stated that cheap passenger trains are now run 10 miles out of London, which is given as 25 cents per week, or $4\frac{1}{4}$ cents for 20 miles.

Should a part of this saving over present rates be attained, the accessibility, and also with this the value of city suburbs, would be so much increased, to the mutual interest of land-owners and railroads, that even suggestions of what may be done will not be out of place, as calling attention to the subject.

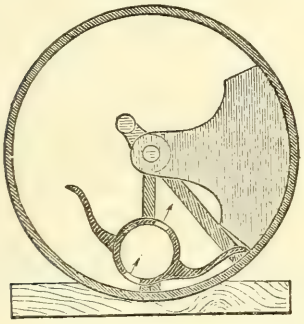
As a large portion of the travelling public is now interested in balloon voyages, it is interesting to know that the generally received opinion, that the temperature of the air decreases uniformly with increase of altitude, is a fallacy. We have Mr. Glaisher's authority for stating that the mean temperature in summer, at 50 ft. from the surface of the earth, is, during evening and night, higher than at 4 ft., and in winter the same relative temperature is always preserved, both by day and night. At sunset, in summer, the temperature is nearly the same for the first 2,000 ft. of ascent; but at night and in winter it increases with the altitude. Thus the phenomena observed near the earth's surface are at variance with those of the ethereal atmosphere beyond.

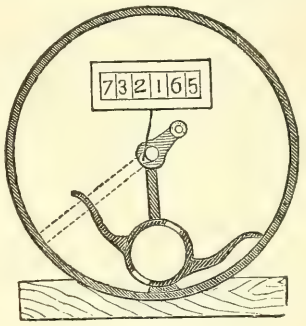
The hydraulic gunboat Waterwitch has been inclined with ballast in the basin at Keyham, to obtain the requisite data for calculating her angles of stability. Thirty tons of iron ballast were placed first on one side of the deck and then on the other, the extreme heel of the vessel being 6 deg.

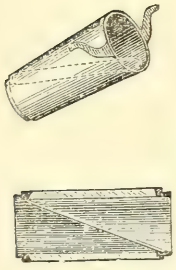
LIQUID METERS.*

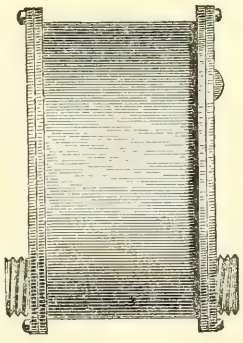
By G. B. MASSEY.

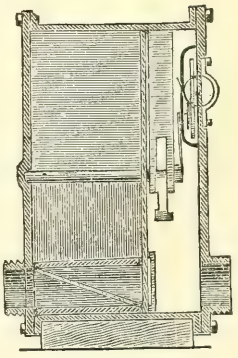
A paper was read on water meters, and the reader, after enumerating many of the different kinds of meters known, and treating upon their respective merits and peculiarities, went into a detailed description of "Massey's central lever water meter." This he considered about as perfect a meter as has yet been invented. It consists of a cylindrical case divided into two compartments or chambers at right angles with its axis. In the larger compartment is a lever or hinged piston as it might be termed, that is a square piston—one side of which is pivoted in the centre of the cylinder, so as to allow it to swing backward or forward, making about three-quarters of a revolution in the case at each vibration. A partition supports the hinge or journal of the lever piston, and through this partition, and parallel to the











line of axis of the cylinder, runs the working valve, which is cylindrical-shaped and opened at both ends, while the division from inlet and outflow of water makes an inclined plane from one end of the valve to the other, the openings into and out of the machine being long narrow slots, one placed on the top of the valve for inflow and the other diametrically opposite in the bottom for outflow. This valve is caused to swing or rock from side to side, so that when the inlet slot opens to the right side on the top, the outlet is opened to the left on the bottom, and *vice versa*. Motion is imparted to this valve by a very ingenious method. In the smaller compartment a weight is hinged on the shaft of the axis of the lever piston, and this is operated by a crank on the same shaft placed in an opposite position to the wing lever or piston. This crank, as the lever piston swings round, catches and lifts the weight until it is just at the

*Paper read before the New York Society of Practical Engineers at the regular monthly meeting March 29, 1871.

end of the stroke, the weight is so adjusted that at the moment it passes its centre of gravity and swinging on the same side as the lever piston, it falls and instantly reverses the valve. The water now entering under the piston forces it over to the other side again, when the weight is lifted and dropped on that side, reversing the openings of the valve and so on.

Mr. G. B. Massey, the inventor of this machine, gave a lucid description of its working parts from drawings on the board; its simplicity is apparent, and the advantages claimed for it seem worthy of consideration.

1*st.* Its compactness and adaptability to all places where the measurement of a continuous stream of water is required.

2*d.* Its lightness and simplicity of construction, as it is composed of but three working parts.

3*d.* Accuracy under large or small flow of water.

4*th.* Its cheapness, as every part can be manufactured by machinery and adjusted by any plumber.

5*th.* The action of the meter must deposit all sand or sediment in the bottom, when it is carried off in the outflowing water. This effectually prevents interference in the accuracy of the machine, which is so often a trouble in meters. Fish can readily pass through (of such size as is ordinarily found into pipes).

6*th.* The power required to operate this meter, like all others, depends upon the workmanship, and under similar circumstances must be less than any double cylinder, as the frictional bearing is less than one-half, according to the amount of water measured and discharged. The arm in an ordinary meter for 1-in. pipe would present a surface of 20 sq. in., and with a head of water of 33 ft. would exert a force of 300 lbs. less the friction, which under proper mechanical construction should not exceed 10lbs. or 1 ft. of the height of water. The weight which operates the valve is so arranged as to reverse or change the flow of water from one side of the measuring compartment to the other at the instant the measure is full, while running fast or slow, and it is impossible for the meter to stop on its centre under any speed or pressure, as is often the case with meters.

FLYING MINES.

From "The Engineer."

One of the most terrible modes of attack and defence known in the art of war is the mine. Here we have a great body of gunpowder confined under the fosse or ditch which troops must cross, or beneath a wall or fort to be destroyed. Fired at the proper moment, this powder charge produces effects which, although localized, are unparalleled in efficiency. Now, were it possible for a besieging army to burrow beneath the town or fortress attacked, and to place a sufficient number of charges of powder in the galleries excavated by the miners, and to explode these charges at the proper time, then would the capitulation or utter destruction of the town follow as an immediate and direct consequence. If the besieged could in the same manner undermine all the advanced positions of the besiegers and blow them into the air, then would the raising of the siege become a certainty. But the work of mining is one of the most tedious and uncertain that armies can execute ; and it follows as a consequence partly of this fact, and partly of the great improvements which have been effected in the construction of ordnance, that mining is now less practised in warfare than at any previous time since the invention of gunpowder. Mines are not less effective than they were before, but substitutes for mining in the shape of explosive shells have presented themselves, which are more easily adapted to the wants of armies. Every shell which falls in a town is in effect, to a certain extent, a little mine. But the value of these mines in destructive power is limited by their dimensions and the small range over which their influence extends. Regular mines in the full sense of the term are, however, inapplicable, except on a comparatively limited scale, to the purposes of attack and defence, for various reasons which it is unnecessary to state. But although the construction of an underground gallery beneath a town or camp may be difficult or impossible of

performance, it by no means follows that mines cannot be effectually planted in a town in quite another way. The work to be done consists in placing a heavy charge of powder beneath or near the surface and firing it, and so long as this is done the effect produced will be independent of the means employed in producing it. If we cannot send in the powder to the heart of a town in bags on the backs of men creeping beneath the walls, then let us send it in cast-iron envelopes over the walls. In other words, let us have mines which shall fly in over head instead of creeping in under foot.

The principle which we have thus indicated was first definitely laid down by Mr. Mallet, and although the subject has been suffered to lie at rest for some years, there is no valid reason why it should not be discussed once more. A great deal has been done to prove that, as a matter of fact and not of theory, shells can be thrown to great distances, which shells shall contain charges of powder so enormous that the effect produced by each shell will be disastrous to the party subjected to their attack. Instead of exploding a single mine, or at most half a dozen mines in the course of a siege, it is possible with adequate appliances to plant and discharge mines in every portion of a work attacked, at the rate of 20 an hour, each mine containing as much as 3 cwt. of powder. Under such conditions of warfare it is hardly too much to say that the defence of fortified positions would become a thing of the past, for in the presence of monster mortars and 36 in. shells, fortresses must capitulate or be destroyed. The moral effect alone produced by a few such shells, each a flying mine, would be simply disastrous.

A pamphlet has just been written by Major-General Lefroy containing the story of the 36 in. mortars of 1855–58, which we heartily commend to the attention of all those who may be fortunate enough to obtain a copy. The pamphlet is a reprint from the "Proceedings of the Royal Artillery Institution, Woolwich," and so far not accessible to the general public. It contains a history, succinctly told, of the inception and construction of the two great Mallet mortars still in the possession of the Government, and a "note" from the pen of Mr. Mallet himself, which clears up and explains a few points whose import would otherwise be obscure. No other account of these mortars is in existence, except that contained in a paper read by Mr. Mallet before the United Service Institution in May, 1858. As part of the practice made with them took place subsequently to that date, the paper is necessarily incomplete. General Lefroy supplies the deficiency.

At the time the mortars were designed we were at war with Russia, and above all things we wished to take Sebastopol. The proposal for their construction was brought before Lord Palmerston, and so convinced was he of the value of the shells which they would throw—which he himself christened "flying mines"—that on the 1st of May, 1855, he broke through all official routine and wrote thus to the Lieutenant-General of the Ordnance :—"I am so fully satisfied of the probable success of Mr. Mallet's scheme, that I am willing to take upon myself, as First Minister of the Crown, the full responsibility of carrying it into execution ; and I therefore request that you will, without the slightest delay, take the necessary steps for the immediate construction of 2 mortars upon the plan proposed by Mr. Mallet."

The work Mr. Mallet had cut out for himself was no trifle. He proposed the construction of a mortar which could throw shells, weighing with their charges nearly a ton and a quarter, to a distance of a couple of miles ; and yet that these mortars should be to a great extent portable. The intended weight of each weapon was about 40 tons. We think it a comparatively small matter nowadays to make a dozen guns weighing 35 tons each, and to put them on board ship ; but Mr. Mallet came before the world with his plans sixteen years ago, when the heaviest gun known in the British navy was made of cast iron and weighed less than 5 tons, firing a charge of but 14 lbs. of powder as a maximum. Mr. Mallet proposed to fire 80 lbs. in his mortar, and he did it, too. Built-up guns were unknown ; Armstrong had not yet appeared on the field, Mr. Fraser was but a youth, thinking perhaps less of guns than of anything else connected with engineering. The history of the construction of Mr. Mallet's two great mortars as told by General Lefroy, is an interesting record of the difficulties encountered by an in-

ventor with a great idea, before his time. Obstacle after obstacle presented itself. Mr. Mallet proposed to build up his mortar of a cast-iron base, 30 in. thick and weighing 7½ tons; of a solid wrought iron chamber 70 in. long, strengthened exteriorly by two layers of wrought-iron hoops shrunk on; a great compound ring of wrought-iron built up of hoops; and of a heavy muzzle ring, the whole held together by 6 great longitudinal bolts. We cannot do better than reproduce here the story of the difficulties met with in carrying out the design as told by Gen. Lefroy: "The late firm of Mare, of Blackwall, tendered on May 7, 1855, to supply the two mortars in accordance with Mr. Mallet's drawing and specifications, within ten weeks of the date of order, for a sum of £4,900 each, including the mortar beds; any weight in excess of 35 tons was to be paid for at the rate of £140 a ton. The offer was accepted by the Board of Ordnance the very next day—an instance of promptitude for which we probably have to thank the vigorous interposition of Lord Palmerston. But alas for good intentions and contractors' vows! The mortars were only reported on the eve of completion in March, 1857, nearly a year after the unexpected termination of the war, and ninety-six weeks after the order. They were really delivered in May. The bankruptcy of the contractors and the physical difficulties encountered in the execution of parts of the order combined to produce this great disappointment. They were then partly the work of Mare & Co., partly of Horsfall & Co., of Liverpool, and partly of Fawcett, Preston & Co. The latter did the turning, boring and finishing of the large forgings supplied by Horsfall & Co. Some delay was due to the unsoundness detected in one of the largest of these when it came to be bored. No one who recollects the constant failures in the Royal Arsenal some years later than this, while the use of Yorkshire iron was persisted in, will feel any surprise at such mishaps; on the contrary, it is to the honor of all parties that the mortars were produced at all."

One of the mortars when finished was tried in Woolwich Marshes. The particulars of the rounds fired are very well given by General Lefroy; but it is worthy of notice that not one live shell was fired, o that the effects likely to be produced could only be arrived at by calculation. That they would be enormous is absolutely certain.

We condense the annexed particulars of the rounds from a table given by General Lefroy.

Ranges of shells of 35.6 in. diameter, and an average weight of 2,594 lbs. at 45 deg., for charges bearing given proportions to their weights.

Round.	Weight of shell.	Weight of charge.	Range.	Observed time of flight.
	lbs.	lbs.	yards.	sec.
1	2376	10	373	..
2	2362	20	907	13.0
3	2596	30	1287	17 0
10	2940	40	1531	16 9
11	2940	40	1497	16.1
12	2940	40	1474	15.0
13	2940	40	1444	16.8
8	2660	40	1629	17 3
9	2660	40	1687	17.5
14	2416	40	1700	17.75
5	2986	50	1738	20.0
4	2352	40	1718	19.0
15	2403	50	2120	21.5
16	2373	50	2100	20 0
6	2604	60	2280	24.0
17	2385	60	2323	21.0
7	2548	70	2654	..
18	2400	70	2758	24 5
19	2395	80	2759	23.0

The depth of penetration of these colossal shells in the soft ground of the marshes was remarkable. Gen. Lefroy tells us that "No 1 was found entire at 6 ft. 6 in.; No. 2 was not found on digging down 12 ft., and could not be felt with a 9 ft. probe; No. 3 was not found on digging 18 ft., and could not then be felt with the 9 ft. probe; No. 4 was found broken into 44 pieces, one of them only 5 ft. 9 in. from the surface, but the great bulk of it at a depth of 14 ft. 6 in.; No. 14 was not found on digging 20 ft. 3 in., but was thought to be felt with a 9 ft. probe; No. 15 was found at a perpendicular depth of 19 ft. 4 in., giving a penetration of 28 ft. No others were found, and the Commanding Engineer, Colonel Walpole, estimated that they had buried themselves fully 30 ft. It would have cost about £21 each to recover them, and there they remain, to astonish, perhaps, geologists hereafter."

Lack of space prevents us from dwelling further on the results obtained. Suffice it to say that all Mr. Mallet proposed to do, he proved himself able to accomplish, as far as the powers of the mortars and shells went. But, owing to the im-

perfect appliances for forging heavy masses, only which were available until a very recent period, portions of the mortar gave way; and to the fact that no pebble powder was to be had, although Mr. Mallet proposed its use, much of this failure was due. The mortar was several times repaired at a comparatively small cost, but General Peel had succeeded Lord Palmerston in office, "a king who knew not Joseph," and he refused to sanction further expenditure; and so the great mortar stood in Woolwich Marshes till 1869, when the bed being decayed the mortar was blown down at the small charge of 12s. 10d. for gun cotton, we suppose to avoid the chance of its falling on some little boy and hurting him; only £150 worth of valuable iron work in the base being ruined at the same time. Who is responsible for this piece of vandalism we do not know.

That 36-in mortars, as proposed by Mr. Mallet, will yet play an important part in warfare, we have no manner of doubt. Their construction would be a comparatively easy matter in the present day. Let us hope that they will be used when the time comes, but not against us. We cannot conclude this slight sketch of General Lefroy's admirable paper better than with the following quotation from its pages:

"It is almost idle to speculate on the effects of shells weighing from 2,300 lbs. to nearly 3,000 lbs., and with bursting charges of 487 lbs. to 405 lbs. The experiment was not tried, and in the interests of humanity we may hope that it never will be; but few will doubt that if the mortars had been completed in time, and Lord Palmerston's intention to send one to the Baltic and another to the black Sea been carried out—and designs for mortar rafts had been actually prepared by Mr. Mallet—it would have been perceived that a new power had entered the European arena. Those heroic soldiers who prolonged the defence of Sebastopol against a *feu d'enfer* had no resources which could have prevented all the defences on the south side, up to Dockyard Creek, from being devastated by a succession of such mines sprung within them, or those on the north side, including the North Fort and Battery No. 4, from sharing the like fate, without the exposure of the mortar vessel to any destructive fire. The casemates of Cronstadt, like everything else of masonry, probably, which the hand of man has put together since the Pyramids, must have crumbled under bolts as irresistible as those which '*fulminantis magna manus Jovis*' discharges; bolts which, according to Horace, only the soul of the upright man can defy."

NEW PAPER-MAKING MATERIALS, AND THE PROGRESS OF THE PAPER MANUFACTURE.

By L. P. SIMMONDS, Esq.

From "The Artizan."

This subject is one of much importance, in which we are all, more or less, deeply interested. There can be no question of the value of paper as a means of diffusing knowledge, awakening thought, calling forth invention, and civilizing the world. It is the handmaid of all arts, of all sciences, and of all trades. Both in an educational and a commercial point of view, an extensive supply of paper, at moderate prices, is of national interest. The laws of supply and demand will, indeed, regulate the question, but discussion and circulation of opinions may result in extended benefit to the paper-maker as well as to the reading and writing public.

The technical question of what is paper, what are the materials of which it is composed, may well be raised, for it led to a trial, some years ago, between the Excise and a paper-making firm, the Attorney-General *v.* Barry. In the edition of "Johnson's Dictionary," published about the middle of the eighteenth century (1755), paper is defined as "a substance on which men write and print, made by macerating linen rags in water, and then spreading them in thin sheets." "Webster's Dictionary," of our own day, enlarges the list of materials, and describes it as "a substance in the form of thin sheets, or leaves, intended to be written or printed on, to be used in wrapping,

etc., and made of a pulp obtained from rags, from straw, from bark, or like materials, pressed and dried."

An historical fact, which was announced 20 years ago, by Dr. Crace Calvert, may be again noticed here. It is that paper, made from the papyrus plant, had lasted from 1,822 years before the Christian era to the eighth century. Egypt was invaded by the Arabians and her trade destroyed. It was then, for the first time, that cotton paper was first imported from China by the Arabians, who, 2 or 3 centuries afterwards, supplied us through Turkey. The manufacture of their flax paper was so successful, that cotton paper was completely laid aside until the commencement of the present century, when once more it expelled from the market the linen paper.

Our word " book" is said to have come from the Gothic word for the birch-tree, some part of which, probably the liber, or inner white rind between the bark and the wood, may have been the most convenient substance which nature has furnished in the northern parts of Europe for portable documents. Other substances than of vegetable origin may be written or printed on, of which we have familiar instances in the present day, in our slates and stone tablets, copper and steel plates, parchment and vellum, gelatine paper, silk play-bills. In olden times, characters, too, were engraven on stone, or impressed in clay, dried and hardened, as the Babylonian bricks, boards of wood covered with wax, plates of ivory and metal, and the leaves of palms were used. The Chinese, Japanese, and Indian papers are made without rags, consisting chiefly of bamboo, the paper mulberry, and other macerated barks and fibres, and their celebrated rice paper, so long a mystery, is now known to be made from the cellular pith of the *Aralia papyrifera*.

Among the influencing causes for the greatly increased demand for paper are the removal of the excise duty on manufactured paper and the stamp from newspapers, the extended number of daily and other journals issued at a cheap price, and the large editions of these called for, owing to the eagerness to obtain intelligence of the progress of the unfortunate war now raging. The increasing commerce of the country must not be lost sight of, and the extensive home and foreign correspondence resulting therefrom, some 700,000,000 letters passing annually through the post. Educational progress also leads to more writing, reading, and book-printing. We have also to remember how many other uses paper subserves, as wrapping material, for cardboard, *papier maché*, *carton pierre*, etc.

Building paper now forms a regular article of commerce in the United States, and more than one public company is doing a large business in it. It is used on the outside of frame buildings, and under shingles and floors, to keep out the cold, and on the inside instead of plastering. It is said to be both warm and cheap. Paper tiles are also used in Saxony for roofing sheds, stables, and barns; and paper collars and other articles of dress have long been in use.

When we consider that 550,000 tons of cotton, 125,000 tons of jute, and 130,000 tons of flax and hemp, were imported and worked up in 1869, besides 53,000 tons of home-grown flax, one would suppose there ought to be a great deal of the waste of these fibres available for the paper-maker. But among the minor tendencies of industries few are more noteworthy than that shown in the increased utilization of waste materials. As competition becomes sharper, manufacturers have to look more closely to those items which may make the slight difference between profit and loss, and convert useless products into those possessed of commercial value.

Our manufacturers have not been slow to appreciate this truth, as is shown in more than one branch of trade. Thus, the refuse blowings and droppings from the spindles and looms of cotton-mills, which were formerly available for the paper-maker, are now found to possess a high textile value, and form the basis of a distinct branch of trade. Millions of pounds of this waste cotton are now used annually in the fabrication of wadding, common carpets, twine, etc. There are a hundred opportunities among the staple industries of the country to secure an equal economy and profit, by turning to proper uses substances now disregarded and thrown away as waste.

In the manufacture of paper, as well as in all other mechanical industries, there has been great progress made, even in the last half century. Chemistry and me-

chanics have each contributed their part. The former has afforded us improved methods for washing, bleaching, and coloring the paper stock, which must yield a different product from what was made by the ancients. The mechanical improvements, too, have been many, both for boiling and running out the pulp. The use of ultramarine, which was at one time almost as valuable as gold dust, has been so extended and cheapened by the labors of the chemist, that its artificial manufacture must be regarded as one of the triumphs of modern science.

Chemistry has also taught us that the cellulose of all plants is the same as that contained in rags, and that, in fact, the fibre of some plants will give us a paper that cannot be made from rags. Not all plants, however, are adapted to the making of paper. Much depends upon the bark, membrane, and fibre, and there is a difference in the purity of the cellulose, in various plants. Chemical tests also show a modification in the fibre of plants. The cellulose of cotton yields a blue color immediately, with tincture of iodine; that of flax does not turn blue until an acid has been added, and hemp requires both acid and considerable time before the blue color makes its appearance. These reactions point to the presence and absence of starch and glucose in different species of plants.

The removal of the excise duty on paper, which took effect in the year 1861, renders it difficult to ascertain with any precision the quantity of paper now made in the kingdom, but we may form a fair estimate by looking at the progress under the duty rate, and judge of the advance from the incentives and stimulus to increased production. The following are official figures of the quantity of paper charged with duty :—

	lbs.
1842	96,693,399
1852	154,469,211
1861	229,502,864

From which we may fairly estimate the present production at 300,000,000 lbs.

Our shipments of paper scarcely keep pace with the increased production and home consumption, which may be attributed to foreign competition, and the colonial paper mills now established in Canada and Australia. The exports are officially given as follows of British paper :—

	Quantity. cwt.	Value.
1860	112,514	£450,589
1865	141,075	447,741
1869	214,416	591,436

The exports and consumption compare as follows, in pounds weight :

	Exports.	Consumption.
1849	5,966,319	126,166,341
1859	20,142,352	187,684,847
1869	24,014,592 (estimated)	276,000,000

In 1869, our export of paper of different kinds, including paper-hangings, was valued at £727,071. The quantity of foreign-made paper received has been annually increasing of late years. In 1869, 412,900 cwt. were imported valued at £690,547, of which 49,926 cwt. were re-exported. The following are the imports of foreign made paper of all kinds in the last three years, in cwt :—

	1867.	1868.	1869.
Printing or writing	174,429	177,220	169,275
Other kinds	151,925	193,387	243,626
Paper-hangings	7,753	5,660	4,435
Total	334,107	376,267	417,306

Besides these foreign figures, we have to consider the quantity used for paper-hangings. The home consumption under this head I can form no estimate of, but give the exports. In 1858, these were stated at 15,000,000 yards, valued at £74,649; in 1869 the official returns gave the quantity of paper-hangings exported at 46,617 cwt., of the value of £132,635.

The paper-makers' licenses, granted during the time of the duty, afford some idea of the briskness of trade, and the paper-mills at work. I find the number of mills rose from 408, in 1785, to 800, in 1829 (the highest number reached). They then declined annually until 1852, when there were 400, at which, with variations of some 8 or 10, the number has since stood. The licenses granted in 1869 were 326 in England, 60 in Scotland, and 22 in Ireland, but all the mills were not at work, and within the last year there have been still further reductions in the number. The "Paper-mills Directory" for 1871 gives the number of paper-mills in work-

ing order in England, in 1870, at 274, besides 12 mills not working, making a total of 286, against 290 in 1869. In Scotland there were 63 mills at work last year, against 58 in 1869. The larger number of paper-mills make brown, cartridge, and such like papers; in England, not more than 100 make printing, news, etc.

If we look at a few of the latest figures regarding the publishing and printing trades, we shall see how important is the question of paper to supply the demand. There are at the present time more than 1,400 newspapers in the United Kingdom, of which 110 are daily, of these 61 are published at one penny, and 34 at one-half-penny each. The mgazines and reviews number 626. The quantity of paper which these require, it is impossible to calculate; but when we find that one London daily paper asserts its average daily circulation to be upwards of 190,000 copies, and if we assume the other London dailies to have each but half this circulation, we can form an idea of the enormous demand for paper, even in the metropolis. Besides the political journals, some of the literary, religious, sporting, and other publications, have very large circulations. But we have also to take books into consideration. According to the "Publishers' Circular," last year there were 4,656 new books and new editions published in Great Britain. In the United States about half this number are issued, and in Germany three times as many. This is independent of the large number of newspapers and books issued in various other parts of the globe. The make and consumption of paper in the United States are nearly as large as our own.

In 1869, we exported 59,291 cwt. of books and imported 11,463 cwt., and the progress in 10 years is shown by the figures of 1859, which were 33,915 cwt. exported, and 6,520 imported.

The price of rags mainly regulates the price of paper, for these are the mainstay of the paper-maker, although now supplemented to a small extent by crude vegetable fibres. The comparative scarcity of rags and kindred substances has rendered their supply, as a main article for paper-making, more and more inadequate, while the importation of esparto fibre from the Mediterranean countries has likewise failed to meet the augmented demand.

The import of foreign rags suitable for paper-making has increased in the last 10 years about 50 per cent. For 20 years it averaged about 10,000 tons. In 1858, it was 11,379 tons, value £246,133; in 1869, it was 17,000 tons, value about £300,000. The aggregate quantity of rags annually collected in the kingdom, with those imported, may be taken at 70,000 tons weight, worth at least £1,500,000. It takes 100 tons of rags to made 70 tons of paper. Notwithstanding the rags produced by our population of 30,500,000 inhabitants, added to the large quantity of jute, bagging, linen and cotton wrappers, old sails, cordage, etc., it will be seen that we are largely dependent on foreign supplies of waste materials for our paper-mills. Linen rags have declined in price from £22 18s. per ton, in 1866, to £19 12s., in 1869, and cotton rags from £13 19s. to £12 4s.

The average value of the rags and other paper-making materials imported in the last 2 years was about £110,000. The quantities are shown in the following return, in tons :—

	1867.	1868.	1869.
Linen and cotton rags.....	18,407	17,860	16,980
Esparto	54,512	95,828	86,334
Other vegetable fibres.....	562	52	1,084
Other materials for making paper....	794	615	1,702
Tons.....	74,275	114,355	106,100

Since the discovery of a method of separating ink from printed paper, old newspapers and old books have entered largely into the paper-makers' material. And the lesson of economy should be learnt, to save for market the waste paper, instead of kindling fires with it and casting it to the winds. Let frugal housewives take a hint, and add the present wasted hundredweights of old paper to the great civilizing agent of the present day.

A correspondent of mine well observes: "For many years it has been pointed out, in every possible way, that an endless variety of cheap materials exists in British tropical dependencies, admirably suited for paper-making, but the ever-recurring difficulty is, not where to get it, nor even what to get, but how to induce any one to bring it, or, if brought, how to

induce any one to be the first to use it. This want of spirit is the dead weight which presses so heavily on the paper-manufacturer."

Owing to the increased demand, and the enhanced price of rags, it has been found necessary to employ other substances for mixing, such as, for instance, straw, esparto grass, and wood. Generally speaking, and especially as regards the grasses, these auxiliary pulps, however, do not fall very far short in price of the rag-product, and thus, while by such admixtures the immediate demands are met, the cost of paper remains high, and acts as a check on that expansion of the paper-manufacture, which is one of the greatest and most urgent requirements of the times.

Wood pulp, chemically produced, although undoubtedly good as to quality, labors under the disadvantage of being too dear; but its production by mechanical agency, which is much less costly, may now be considered as brought to great perfection by means of improved machinery, amongst which Voelter's system claims an undoubted superiority, at any rate, in localities where the raw material is abundant enough to afford supplies for their great converting capacity, and its action is facilitated by a sufficiency of water-power. Under such conditions, each one of M. Voelter's engines of the ordinary size is capable of producing 17 cwt. of pulp daily, at a cost varying in proportion to the nature of the motive power employed, the price of the raw material, the facilities of transport, the rate of wages, and other contingencies.

In all these respects, Sweden, according to a detailed report of Mr. Gustaf Josephson, offers peculiar advantages. The supply of soft pine wood, perhaps the most suitable of all for the manufacture of paper-pulp and pasteboard, is there practically unlimited, and obtainable at a price of 1½d. to 2d. per cubic ft., whereas in Germany, where a number of such works have been in existence for some time, and have supplied English markets with their produce, which is, however, mostly of inferior quality, the same material is worth about 3d. per cubic ft. on an average. Aspen wood is likewise plentiful and cheap in Sweden.

There are now about 160 of these wood-pulp machines at work on the Continent. Some of those in Germany and Belgium, and about 30 of those situated in the Scandinavian countries, where material is abundant, send their pulp to England as a paper material.

The first mode of preparing wood-pulp from the pine and other white woods, was to reduce it into thin shavings, which were soaked in water for 6 or 8 days, and then dried and ground into powder by a corn or crushing mill. This powder was mixed with rags, so as to make a pulp, and the ordinary operation of paper-making was then proceeded with. The principal defect of this material was the shortness of fibre.

The preparation of wood-pulp has not hitherto been sufficiently successful to make it rival rags, esparto, or straw. Further experiments may, however, go far to remove the present defects.

Esparto, as it is called in Spain, and alfa on the African coast, is a coarse, rushy grass, which has long been used as a fibrous material for rough yarn and cordage, and more than 30 years ago was recommended as a paper-making material, but was only brought into extensive use about 16 years ago, by the persevering efforts of Mr. Thomas Routledge. No material alteration in the machinery or apparatus is required for working esparto, and much less power is necessary. According to a practical authority,* the successful working of this fibre depends mainly on the careful and proper adjustment and strength of the chemicals employed. The quantity of soda-ash required for neutralizing the gummo-resinous matters in the fibre, so as to admit of its being made into pulp, is very large, though not so great as is required for straw; and the fibre, unlike rags, never having before been subjected to bleaching or other chemical treatment, also requires very much more bleaching powder to bring it to color suitable for printing paper. The quantities required are from 5 to 6 times as much as for cleansing and bleaching the coarsest rags.

In a late circular of Messrs. N. W. Chittenden & Co., fibre brokers, they state that, "during the past year, numerous small importations of various descriptions of fibre have occasionally been made, and ready experiments have been afforded to

*Mr. W. H. Richardson, on the Paper Manufactures of Northumberland and Durham.

test their capabilities, yet none has been found as a practical substitute; and during the past 12 months upwards of 93,750 tons of esparto have been imported into the United Kingdom, and although there has been but little falling off in the importations of other material previously used, the price of esparto still keeps at about £10 per ton. What effect this may have upon manufacturers who have been at a heavy expense in erecting machinery to work this article, when it was supposed that any quantity could be had at £6 or thereabouts, with but slight fluctuations in value likely to occur, we cannot say; but it seems an astonishing fact, that although the consumption of paper has been greater than ever, and that most raw materials from which it is produced have risen, our makers have not combined to raise the price of their production in proportion.

A correspondent, reading the discussion which took place last year, in the "Standard," on paper materials, sent me specimens of pulp which he had prepared in Jamaica, under difficulties, from various substances, such as the bamboo, different fibrous plants, simply crushed and macerated, and wood pulp from trees of large growth. The fibrous plants of Jamaica, he observes, are numerous, and deserve a greater amount of attention, but hitherto nothing of a substantial or permanent character has been done practically. The Jamaica papers have since taken up the subject. A recent "Kingston Morning Journal" has the following editorial remarks:—"It seems, from all we can gather, that there is a market for our fibres, and such material as they convert into pulp, if only we would set to work to produce them. There is no lack of material for this purpose. From one end of the island to the other it abounds, of various kinds, and of various qualities. It is really pitiful to ride about the country, and see the acres of penguin that uprear their heads and spread themselves about as they can find space, preventing all other vegetation from thriving, while it is itself practically of no use whatever, and may be regarded as an encumbrance of the ground. What a mine of wealth we have in these same penguin plants, if only people would take the trouble to set about to extract it. Years ago, the matter was talked over, and it was then set forth that the fibre is abundant, is strong, is of excellent quality for manufacture into certain kinds of cloth and cordage, while the material is as 'common as dirt' in the country. It is a pity that so little—indeed, nothing beyond the trying of a few experiments—has ever been done to turn it into practical and useful account. Besides the penguin for the production of fibre, there are the plantain and the banana plants. There is not a peasant or small settler who does not cultivate them pretty extensively. Travelling through the mountain districts, the very first thing to apprise the belated traveller that he is getting within the circle of humanity, is not so much 'the watch-dog's honest bark, baying deep-mouthed welcome,' or unwelcome, as the sight of those graceful plants, waving their leafy wings in the soft night air that plays around them; and, when the village is reached, there is not a cottage but is surrounded by them; there is not a garden in which they do not abound. Then there are the fields, or 'grounds,' that lie beyond the confines of home, on the higher lands, in which plantain and banana plants are to be seen also growing abundantly. These require little or no cultivation. They propagate themselves by means of the suckers that shoot out of their roots, and, except occasionally pulling the grass from around those roots, the trouble they occasion the husbandman is of an infinitesimal character. The plants abound in fibre of a coarse character, that would be valuable in the manufacture of cordage, while the pulp might be converted into paper of a coarse description. All the use that is made of the plant at present is to cultivate it simply for the sake of its fruit. The other portions of it are thrown down, and lie on the ground and rot. There is some singular fatality attending this country, that so much that is useful, so much that is really valuable, is allowed to grow up and then to rot, when it might so easily be converted into money."

The paper-yielding stems of the plantain and other indigenous plants have been too long neglected. Useful and tough kinds of paper have been made from them. Simple pressure between rollers and washing would appear to be sufficient for the separation of the fibres of most of them.

A Jamaica correspondent sent me by the last mail a copy of a daily paper, which reports that the Governor, "Sir John Peter Grant, is turning his attention to the development of the fibrous wealth lying latent and running to waste in this island. In plainer language, his Excellency thinks there is money to be made by preparing for market the numerous varieties of plants growing without cultivation all over the country, from which fibrous materials may be extracted, for the manufacture of cordage, textile fabrics, and paper ; and we learn that he is about to bring to this country a person experienced in the extraction of fibres from the plants containing them, if not for the further conversion of the materials so evolved into manufactured articles. At present, we do not go so far as to insist on the manufacturing part of the project, but we would content ourselves just now with an impetus, such as it is said Sir John contemplates, to the growth and preparation of the raw material for the purposes of the manufacturers of Manchester, Glasgow, and other towns and places in the United Kingdom. We are not so ambitious as to 'despise the day of small things.' Therefore, for the present, at least, we should be quite satisfied to witness the shipment of a few tons of raw material spoken of, by way of a beginning to a new industry which, we are convinced, if followed up with spirit, is calculated to provide a handsome living, if it do not lead to affluence, to such persons as may engage therein, provided that they set about the work understandingly, and carry it on skilfully, and at the lowest possible cost. Nor does it appear to us that any very elaborate process, involving complicated and costly machinery, is absolutely necessary for the purpose of separating from fibre-producing plants, such as we have in such luxuriant abundance in the island, the ligaments, which form their strength and real substance, from the feculences which keep them together in a state of cohesion. Now, the Jerusalem dagger, as well as the common dagger (this I believe to be *Yucco gloriosa* and *Aloefolia*), grow luxuriantly all over the island. In regard to the latter, it is too common to render necessary one word about it. The other variety is not so well known. The leaf is more soft and pliable, and seems to us to be more adapted to the manufacture of cordage, and perhaps for textile fabrics, than the better-known kind. We can assure our readers—and we now address ourselves more particularly to those abroad, who are in any respect interested in spinning and weaving—that the fibre of the two plants we have already named require no bleaching—at least it seems so to us ; for immediately as it is cleaned, washed and dried, it is as white as the best bleached linen thread, and much whiter than the printing paper on which this article has been written. Nor this alone. It is as fine as the finest silk as it comes from the worm, tough, and elastic. Unlike the plantain fibre, which breaks if made into a knot, it is tenacious, and can bear any complication of knots without snapping. This is one of the greatest desiderata in all fibres, whether for cordage or textile purposes. Then, if we mistake not, whatever substance is suitable for cordage and woven fabrics is equally suitable for manufacture into paper, with this advantage, that, for the latter purpose, the waste and refuse, embracing short, broken fibres, may be used with equal benefit to the long, sound fibre employed for the other purposes named. And as there has for many years existed an outcry about the scarcity of rags, which the wars now raging will serve to enhance, from the demand for lint and bandages for the wounded, it seems to us that we have hit upon a plan—which, by the way, we did as long ago as the time of the Crimean war—whereby the wounded may be benefited, without in the least inconveniencing the paper manufacturer. We may add to this, that this latter will be able to turn out a superior article, because he will have for a stock a raw material much stronger than the old rags he has been in the habit of employing in his manufactory. We have already alluded to the marked whiteness of the fibre of the dagger. In this, as well as in its greater flexibility and tenacity, it is far superior to the fibre of the plantain or banana of any description, which would require considerable bleaching for either paper or any of the textile fabrics."

The bamboo is not a new paper material, although it has only recently been introduced into this country for that purpose. Much of the common Chinese

paper is made from it, as may be seen described in Herring's work on Paper, p. 31. The American paper-makers have for some time drawn supplies from British Guiana, Jamaica, and other parts of the West Indies. In the paper which I read before the Society 2 years ago,* I called attention to what the Americans were doing with bamboo as a paper material, and this seems to have drawn attention here to this gigantic grass.

During last year, some supplies of a very excellent new material were imported from the Portuguese settlements on the west coast of Africa, where considerable quantities may, it is said, be obtained. It is the fibrous bark of a Sterculiaceous tree, the baobab (*Adamsonia digitata*), and, from its tough fibrous net-work, it would in quantity be very valuable to the paper-makers. It is not a tall tree, but attains gigantic dimensions in growth, being described by travellers as a "vegetable monster," and "behemoth of the forest," being frequently 80 or 90 ft. in circumference. Livingstone asserts that nothing short of boiling the tree in sea-water could possibly destroy its power of vitality. Constantly barked by the natives, the tree nevertheless retains its full vigor, and a removal of the very core or centre of the stem would not, according to that traveller, affect the existence of the tree ; and "the reason is," to quote his own words, "that each of the laminæ possesses its own independent vitality; in fact, the baobab is rather a gigantic bulb run up to seed, than a tree." This tree or an allied species (*Adamsonia Gregorii*) is found in the West Indies and North-Western Australia. The bark fetches readily here £14 to £15 per ton. This bark furnishes indestructible cordage, and a close thread used for cloth and ropes. Ropes made from it are said to be so strong that there is, in Bengal, a saying, "as secure as an elephant bound with baobab rope."

At a late meeting of the Scottish Paper-makers' Association, the chairman urged that the attention of makers should be turned to the introduction of other materials to cheapen the cost of production, or to increase the percentage of paper yielded by the materials now in use. Wood-pulp might soon be more generally used, as, from recent information, there were means lately discovered, and soon to be patented, whereby the fitness of this material would be greatly improved, and its price be exceedingly moderate. An inquiry into the practicability of growing a vegetable fibre at home, as a substitute for esparto, was held by several Scotch paper-makers with the Chamber of Agriculture, but no definite conclusion was arrived at. The general opinion, however, was, that straw was the cheapest and best material that could be had ; but great difficulty exists in obtaining large supplies, owing to the lease stipulations requiring it to be consumed on the farm. The market price of straw here being also £6 per ton above what it is in Sweden and Belgium, it can be imported from those countries cheaper than it can be bought here.

The vacoua sugar bags, which are made from the tough longitudinal fibres of the leaves of the *Pandanus utilis* and other species of the screw pine, are a useful paper material. Three millions of these bags are made annually in Bourbon, and a large number also in Mauritius. The leaves are cut every second year, and each plant yields enough for two large sacks or bags. The leaves yield paper of good quality, light and strong.

In Australia, attention is being directed to the utilization of local materials for their paper-mills. At the recent Intercolonial Exhibition at Sydney, in September last, a bronze medal was awarded to the Paper Company for its brown, printing, and news-printing, made at their Liverpool mill. The brown paper was chiefly made from refuse New Zealand flax ; the printing is used by the local journals. The hand-made papers, shown by Dr. Mueller, of Melbourne, proved from what a great variety of vegetable fibres paper can be made ; but the difficulty to be conquered is commercial—not mechanical—the cost of reducing much of the fibre into paper being prohibitory.

A select committee of the House of Assembly of South Australia reported, in August last, that thousands of tons of material, equal to any demand, and suitable to the manufacture of fibre, is growing extensively in various parts of the colony, and a large proportion on the Crown lands, while the cutting of it does

* "Journal," vol. xvii., 1869, p. 175.

not destroy the plant, but tends to improve it. The committee report their opinion that a new and valuable industry might be opened up, not only to supply the colony with material useful for various manufactures, such as hemp, rope, and paper, but there would also arise a very large European trade. The committee, therefore, recommend that a bonus of £2,000 be offered by the Government for the first 500 tons produced in the colony.

Dr. Mueller, in an elaborate article on the barks, foliage, grasses, rushes, etc., of Australia suited for paper-making,* remarks that forest regions and coast lines, swamps and flats subject to inundations, should prominently yield the material for the factory; for, on open pastures or otherwise occupied tracts of country, even paper material cannot be harvested for an unlimited period, at the expense of the soil, with impunity. In factories situated in the vicinity of forests, the soda expended in paper manufactures might be profitably regained by evaporation of the ley, and crystallizing it with coal or sawdust. In viewing (he adds) the immense supply of various kinds of paper material here cheaply available, there is no reason why they should not form, closely pressed, an article of export probably less inflammable than rags; and, still more, it may safely be anticipated that, together with the consumption of rags in local factories, the new articles indicated will largely enter into the fabrication of paper, the product of Victorian industry.

I have not thought it necessary to take up the time of the meeting by an enumeration of all the Australian materials on which Dr. Mueller has experimentalized, with more or less success. Many of these have been repeatedly brought under notice, others are new; but I have specimens of various papers made from them here, for the inspection of those interested. These papers have not been subjected to chlorine, or drawn through size.

In the reports of the jurors at the New Zealand Exhibition of 1865, it is stated that New Zealand produces a number of fibrous plants and grasses suitable for the manufacture of paper, a branch of industry which must, at some future time, become an important one. The bountiful supply of pure water with which almost every portion of the colony is blessed, and the facilities which exist for the erection of mills to be driven by water power, combined with the abundance of paper-making material, which grows in profusion throughout the colony, constitute New Zealand as *par excellence* a favorable country for the production of paper for the supply of this and the other Australian colonies. With regard to paper-making material, the *Phormium tenax* must again occupy the first place.

Not only is the fibre admirably suited to that purpose, but it is the more valuable, inasmuch as the refuse particles of fibre, after its preparation for spinning, are available for the manufacture of paper. In the event of the cultivation of the *Phormium tenax*, there will always be a large quantity of damaged, and what would otherwise be waste leaves, which would be valuable to the paper-maker. Forty years ago, paper was made of it to print an edition of a work by Mr. John Murray, of Edinburgh, on the plant and its uses. The peculiarity of this paper is its tenacity, which property should make it valuable for documents and printings to stand a great deal of wear and tear. No better paper could be used for bank-notes, or for the printing of valuable standard works.

Many of the native grasses of New Zealand are sufficiently fibrous for the manufacture of paper, and the profusion in which they grow on almost every variety of soil, and under every condition of the climate, is an additional reason why efforts should be made to utilize them. One variety of grass in particular claims attention, from its resemblance in many important features to esparto; this is the "snow grass" of the tussocky grasses of the colonists (*Schœnus pauciflorus*, Hooker), which grows rank and luxuriant at high elevations and on barren soil, in the interior of the Middle Island. Experiments have been made at Dunedin as to the paper-making qualities of this grass, and the trial was sufficiently satisfactory to establish its value for the purpose. But while I direct attention to these paper-making materials, I fear Australia is too far distant to be thought of for any extensive supply of raw material, and we must look to nearer quarters, such as the shores of Northern and Western Africa,

* "Journal of Applied Science," August, 1870.

Brazil, Central America, and the West India Islands.

Seven or eight years ago, in a work which I published on the utilization of waste substances, I suggested that the woolly fibre adhering to the hulls of the cotton seed might be economized in the manufacture of paper, and I am glad to find that this, like very many other hints thrown out, has since been carried into practice.

At the last meeting of the British Association, a paper was read by Mr. Thomas Rose, of the firm of Rose & Gibson, of Sankey Mills, Earlstown, on the further utilization of cotton seed, and especially by converting the short cotton fibres adhering to the husk of the herbaceous cotton, and the husk itself, into paper. The seed yields, in round numbers, 50 per cent. of kernel and 50 per cent. of fibrous husk. The kernel yields about $\frac{1}{3}$ crude oil and $\frac{2}{3}$ cake. The fibrous husk gives an average of 30 per cent. pure fibre. The process of operating is this, the cotton seed is fed between a pair of rollers, running at differential speed, and not quite in contact. This cracks the husk or shell, and allows the solid kernel to fall out and be easily separated. A system of riddling further separates a great deal of the dry, broken husk. After this it is boiled in caustic soda, in a revolving boiler, by which means much of the remaining husk is got rid of, and final washing so completely liberates the cotton that it is ready for bleaching. After this process, it is reduced to pulp, and converted into paper. Supposing this to prove a success commercially, of which Mr. Rose (who is now in America on the subject) appears to be more sanguine, it will further utilize a waste product on which I have often spoken in former years in this room, and add something to the wants of the paper-maker as regards raw material.

In a late number of the "New Orleans Picayune" (Nov. 10, 1870), I find an article giving elaborate statistical calculations about the value of the cotton seed and its subsidiary products; but I am a little sceptical as to American estimates and figures, particularly when the money value of the oil, oil-cake and ashes of the hulls, as a fertilizer, are set down at the large sum of £11,000,000 sterling, or equal to $\frac{1}{4}$ of the value of the incoming crop of cotton. The quantity of cotton seed from an American crop of 3,000,000 bales is represented to be 2,250,000 tons. Now, sharp as our American cousins are in turning matters into money, they do not appear yet to have thought of utilizing the fibre. If this is all woolly seeded cotton, the weight of seed spoken of ought to yield about 300,000 tons of pure fibre, worth, to paper-makers, not less than £7,500,000. And this is quite irrespective of the bark of the stem of the cotton plant, which I have not yet heard is economically used.

Looking at the utilization of this small cotton seed fibre, I see no reason why another material should not be available, in the fibrous husk or covering of the betel nut of India (*Areca catechu*), which is in such general use throughout the East. The fibre has a soft and cotton-like feel, and is capable of being spun into twine. Immense quantities of these husks are now thrown away, and, as a paper material, they ought to be collected in large quantities and at little cost. From Ceylon, about 70,000 cwt. of these nuts are shipped annually, and large quantities from Penang, Sumatra, and Travancore, and from other quarters there are also large exports.

One material has been again brought into notice, the New Zealand flax lily (*Phormium tenax*). Twenty-five years ago it was shipped from the colony as a paper material in solid lumps, to lessen freight. The paper obtained from it is the strongest of all. The subject from that time to the present day, has been one of almost constant discussion. The readiness with which the large richly-fibrous leaves can be turned into pulp for a very substantial paper, entitles the plant not alone to consideration, but also the fact that it may be permanently established with the greatest ease in any swampy ground.

The leaves of many palms, but chiefly of the dwarf palm *Chamœrops humilis*, *Phœnix spinosa*, and other species, have lately been imported for paper-making, and are found useful if well separated from the leaf-stalk, which is hard, stiff, and brittle.

A patent has lately been taken out for applying the creeping stem of the antidote cocoon (*Feuillæa cordifolia*) as a paper material. This is a cucurbitaceous perennial scandent plant, climbing on the highest trees, very common in Jamaica.

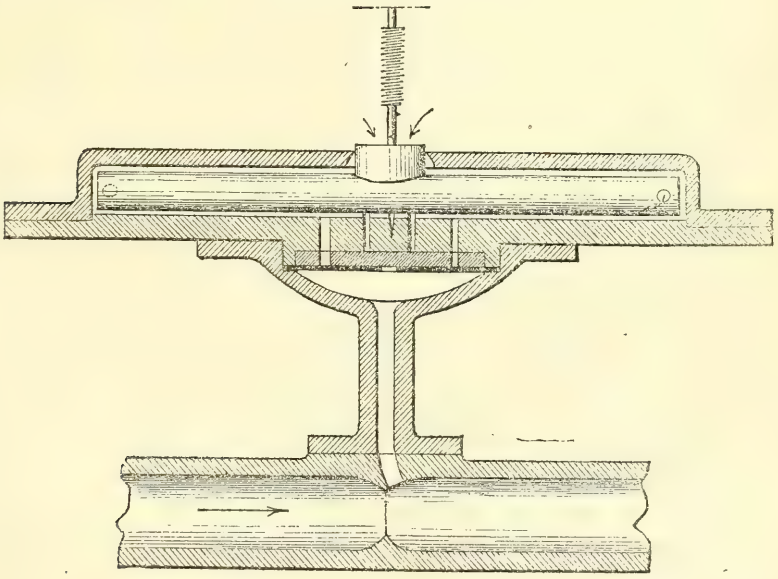
It has been well remarked that it is from a careful observation of the laws of vegetable growth and decay that man has been enabled to take advantage of many of the beautiful vegetable products that lie scattered about in luxuriant profusion, and in proportion to the pains he takes to observe the laws of nature, and the judgment he displays in applying this knowledge to scientific or useful purposes, so are the results beneficial to the community at large. One man looks, perhaps, at the chemistry of vegetables, another merely at the physiology, while a third considers it useless to waste time with such abstruse studies, and inquires merely what is the mercantile value of fibrous substances, and how cheaply they can be brought into the market. Now, all these inquiries have their relative importance.

In this superficial inquiry on paper-making materials, I have merely touched upon a few of the more prominent, without going into practical details, which can best be supplemented by those present who are specially engaged in the manufacture. The subject will not have been introduced in vain if any of the facts or suggestions I have brought forward shall result in benefit to those who are more specially interested in the manufacture of paper.

A NEW WATER-METER.

Translated from "The Polytechnisches Journal."

Flowing water may carry air along with it, either in consequence of motion through air or contact with it. The maximum effect of this kind occurs with a stream of the form of the *vena contracta*, in which the quantity of air conveyed is in proportion to the quantity of water discharged.



The apparatus of J. A. Muller, of Amsterdam, shown in section in the figure, is based upon this fact. The stream of air induced by the flowing water is employed to set in motion a small turbine. The drawing represents the tube through which the water to be measured flows. The inside is connected with the box in which the turbine (a kind of reaction wheel) is placed. Between the box and the tube is a rubber valve fitted to a metal plate, to cut off the water from the train.

It is easy to see how the apparatus acts. As soon as the water moves in the tube, a current of air is caused, and by withdrawal of the air from the box the tension within becomes less than that of the ex-

ternal air; hence, a motion of the external air inward (shown by the arrows), and the reaction of the air flowing from the turbine, causes a rotatory motion.

The axis of the turbine carries a screw, connected with a train of wheels, by means of which the number of revolutions is shown upon an index-plate. Upon this is cut a spiral line, with several revolutions, along which an index moves, showing the number of revolutions by the distance of its extremity from the middle point. A spring brings the index back to its place.

The train connected with the index-plate is placed in an air-tight cap, provided with an opening for discharging the air necessary to move the turbine. The air is dried and filtered before entering.

Cheating is prevented by means of a peculiar stopcock, or by a rubber ball filled with air, which expands when the air is cut off, and sets another train in motion.

The apparatus is intended to serve as a gasometer, or as a tachometer for the determination of the velocity of streams. It has been tested, and proved accurate, in experiments under heads varying from 2 in. to 150 ft.

THE SPECIFIC HEAT OF AIR.

By F. R. VON SCWIND.

Translated from "The Polytechnisches Journal."

In the latest works on physics, two values for the specific heat of air are given; one, $c = 0.1686$ for constant volume; the other, $c' = 0.2377$ for constant pressure.

These values were found empirically before the operation of heat as a living force, according to mechanical laws, was determined. If these are applied, c' is found not to apply to the single case of extension, as the following shows.

A heat-unit is a quantity of heat which raises a kilogramme or cubic decimeter of water one degree Celsius.

In a constant volume of atmospheric air of zero temperature, at 760 millimeter, by barometer, the same quantity of heat will produce a temperature $t = \frac{1}{s.c}$; s being the specific gravity of air (0.0012932), and c the specific heat for constant volume; the air consequently not being capable of expansion.

If expansion takes place with unchanged temperature, the change of volume $v = a\ t = \frac{a}{s.c}$; a being the coefficient of expansion for one degree (0.003655).

At the above-mentioned barometer-height this expansion takes place under a pressure $p = 103.34$ kilog. to the square decimeter, and the work required is $A = v\,p = \frac{a\,p}{s\,c}$ meter kilograms.

The quantity of heat (w) required, if k is the mechanical equivalent (424 met.-kil.) for a unit of heat is

$$w = \frac{A}{k} = \frac{a\,p}{s\,c\,k} = 0.41$$

of a heat unit.

Hence, if with $c = 1$ heat unit, the temperature of the air is raised without expansion t degrees, requiring $c' - c$ heat units $= 0.41$, the total required is 1.41 heat units; multiplying these values by 0.1686, we get $c = 0.1686$ and $c' = 0.2377$, as above.

This result shows that the three values c, c', and k, though found by entirely different methods, agree very exactly; and it appears that c' comes directly from c and k, and that it is correct only for a barometer height of 760 millimeters, and therefore has no constant determinable value.

Knowing the heat unit $c = 0.1686$, we have sufficient data to determine a required amount of heat under all possible conditions of expansion and pressure; and any other method seems useless and uncertain.

The equation $k = \frac{A}{c' - c}$ giving $W = c' - c = \frac{A}{k}$ is taken from "Schmid's Mechanick der Gase."

The mechanical equivalent of heat would be proven in an entirely different way; the above is a proof of the correctnes and mutual dependence of the three values of c, c' and k.

The determination of k has made the values of c' unnecessary; and it would be eliminated if the heat-unit for every barometer height were known.

CONSIDERATIONS AFFECTING THE VALUE OF DISTANCE SAVED IN THE LOCATION OF RAILROADS.

By H. HAUPT, C. E.

In the location of a railroad and in the choice of plans of construction, an engineer is not always at liberty to adopt a high standard in gradients, curves, and permanency of structures. He is often controlled by financial considerations and forced to resort to temporary expedients to bring the cost of the work within practicable limits.

In the comparison of lines, distance is a very important consideration, and the value of distance saved upon the shorter line is essential in determining questions of location.

This value is not the same upon all roads and is not constant even upon the same road, but increases with the development of the traffic. The first step, therefore, in the determination of this value as an element of location, must be an estimate of prospective business.

As a guide in the solution of such questions, an illustration will be given from data furnished by a recent report of the Pennsylvania Railroad Company:

Items of Freight Expenses increased proportionately by increased Tonnage, from Report of Pennsylvania Railroad Co. for 1869.

Brakemen	$493,538
Car cleaning and inspecting	67,472
Cars (repairs freight)	961,286
Coal	505,450
Conductors	184,210
Cotton waste	17,057
Engineers and firemen	448,909
Frogs	28,011
Iron rails	576,095
Labor at stations	152,883
Laborers (motive power)	170,824
Locomotive repairs	991,561
Oil, tallow, sponge, wool, etc.	51,209
Tallow motive power	27,898
Teaming	109,125
Tools and machinery repairs	112,010
Wood and labor	81,957
Total freight expenses which are increased by tonnage	$4,979,495
Total freight expenses, permanent and variable	9,035,031
Percentage of variable items	55
Mileage of freight trains	6,904,888
Tons moved 1 mile	752,711,312
Whole cost of moving freight per ton per mile	$1\frac{3}{10}$ cents.
Cost of variable items per ton per mile	.66 "
Cost of rails per ton per mile	$\frac{3}{4}$ of 1 mill.

On the Philadelphia and Erie Railroad the renewal of rails amounts to $\frac{1}{3}$ of a mill per ton per mile, but this item is extremely variable on the same road.

The expenses which are increased by extending the length of a road including those enumerated in former list	$4,970,495

And also,

Ballast	89,732
Cars (road and hand)	22,450
Chains	98,344
Cross ties	198,510
Laborers' tools	206,925
Road bed materials	102,974
Snow and ice (removing)	15,222
Spikes	21,868
Superintendents	26,403
Switches	19,551
Telegraph	18,837
Repairs of tools	37,822
Labor (repairing track)	453,815
Watchmen	98,710
Total freight expenses increased by mileage	$6,381,658
Cost of running freight trains per mile of increased distance, about $1.00 each day.	

The whole freight expenses on the Pennsylvania Railroad, including General Office station and permanent expenses, amounted to 1.30 cents per train per mile.

To ascertain how large an expenditure would be admissible to reduce distance on the Pennsylvania Railroad, allowing capital to be worth 6 per cent., the number of trains passing a given point must be determined.

As the tonnage eastward exceeded the tonnage westward in proportion of nearly 4 to 1, only the eastern trains should be extended, and then an equal number added for return trains. The distribution can be best determined by means of the table of loaded cars passing any given point.

At Altoona 153,202 loaded cars passed eastward; the same number, of course, returned partly loaded or empty. Allowing 16 full cars to a train, the number of trains both ways would be 19,200; add 4,800 passenger trains, and say 2,000 road, ballast, and material trains, the total number would be 26,000, costing $26,000, which, at 6 per cent., is the interest on $433,000, the capital which represents the

equivalent at this time of one mile of distance on the Pennsylvania.

When the Pennsylvania Railroad was constructed a mile of distance saved was considered worth $53,000 or $10 per foot; but the most vivid imagination never anticipated the expansion which the volume of business on that road has attained. Had the engineer been required to estimate the value of distance on the basis of present tonnage, and construct the road accordingly, it would probably not have been constructed at all, as the capital could not have been provided.

In view of these facts, the proper course obviously is to locate an important line on which a heavy traffic will be developed, with reference to the future, and then by temporary lines and trestle road reduce the first cost of construction to suit the finances of the corporation engaged in construction. This is a wise policy, for the reason that, if the road does not prove a success, no improvement on temporary lines will be required; and if a success, then capital for improvement can be procured without difficulty and without paying interest on bonds or dividends on stock; but if a cheap and temporary line is first located as a basis of operations, it cannot be corrected subsequently without an entire relocation and construction.

It appears from an examination of the figures presented, that while the average freight tonnage of the Pennsylvania Railroad in 1869 has cost $1\frac{1}{2}$ cents or 12 mills per ton per mile, an increased tonnage could be carried at a cost of 55 per cent. or $6\frac{6}{10}$ mills. These proportions result from the large volume of business. On roads carrying less than 500,000 tons the cost per ton per mile is from 2 to 3 cents, and the percentage of cost of an increased business only from 30 to 40, a consequence of the fact that on roads doing a small business, the general and stationary expenses bear a larger proportion to those which are variable.

SUSPENSION BRIDGES*.

In the present day of long-span bridges, more particularly those of suspension, across the wide rivers of this continent, it may not be uninteresting to the civil engineer to trace the successive improvements in their mode of construction, and to fix definitely the claims of inventors and designers to such improvements as they may be respectively entitled to. I am not aware that the subject has been treated in this light before, and therefore, in view of its importance, make no further apology for occupying your attention.

I found in an old book the following sentence :

"The invention of the suspension bridges by Sir Samuel Brown, sprung from the sight of a spider's web hanging across the path of the inventor, observed on a morning's walk, when his mind was occupied with the idea of bridging the Tweed."

The artificer of the web who really guided Sir Samuel Brown, was the American engineer, James Finley, of Fayette county, in the State of Pennsylvania. He, in the year 1796, built the *first regular* suspension bridge across Jacob creek, on the turnpike from Uniontown to Greensburg, in the State of Pennsylvania. He obtained the first patent on this object from the Government of the United States, and the book, "Treatise on Bridge Architecture, by Thomas Pope," published in New York in the year 1811, spread this ingenious invention over the whole world. Some English and French authors, and even Pope, tried to diminish Finley's merits by attributing this invention to the Chinese and Indians, but these people used only ropes or common chains, fastened to trees, and the path was directly on the catenary, without suspended floor.*

The development of the art of bridge

* A paper read before the American Society of Civil Engineers, by CHARLES BENDER, C. E.

* At the discovery of America similar constructions were found there.

Humboldt found in the year 1802 a suspension-bridge across the river Chambo, in Peru, the ropes being 3 ft. thick, made of roots of the Agave Americana. The span was 40 ft.

In the year 1515 the Landsknechte, a kind of regular troops (Germans and Switzers), built a rope bridge across Padus river, in Italy, which they passed with artillery.

In the year 1595 Admiral Coligny, in France, made a rope-bridge near Poitier.

In the year 1734 the army of the Palatinate of Saxony, in Germany, built a chain-bridge across the Oder river, near Glorywitz, in Prussia.

The bridge across the Tees, in England (1741), 70 ft. long and 2 ft. wide, was like those constructions in China and Thibet, having chains fastened to timbers, the planks laid on them directly.

building is showing and proving how deeply James Finley had studied his task, and how much we owe to him.

The principal features of his invention consisted in the application of artificial stone abutments, in the introduction only of two chains, one at each side of the bridge, the links of which were as long as the distances between the cross-bearers or joists. Finley applied $\frac{1}{7}$ of the spans for the deflections of cables, introduced suspension rods and stirrups to support the joists, and arranged the anchor chains at the same angles as the main chains, to avert powers acting to throw down the piers.

The most interesting of the novelties, and one upon which Finley apparently laid a great value, was the arrangement for distributing the load over a great extent of the bridge, thereby aiding to divide it over many suspenders, and to stiffen the otherwise movable floor against change of shape.

His specification reads as follows :

"To bind and connect the whole that they have the same effect as a *platform of one piece*, 4 or more joists will be necessary for the upper tier—to extend from end to end of the bridge ; each will consist of more than one piece, the pieces had best *pass each other side by side*, so that the *ends may rest on different joists* on the lower tier. The splice will then extend from one joist to another of the lower tier, and must be bolted together by one bolt at each end of the splice. The planking floor is laid on the upper tier."

Herewith the inventor formed strong beams, continuous from one end of the bridge to the other, and the continuity itself gives the utmost certainty, that these beams, which were no directly bearing parts, had the aforesaid important object, to stiffen the floor, prevent greater changes of form, or, in other words, to neutralize the momentum arising from loads and wind.

The method employed was sufficient for the spans at that time in use, and, in connection with the stiff railing, fulfilled entirely the conditions necessary for a good bridge for common traffic. For the time in which Finley lived, his bridges were astonishing structures in reference to the insufficient knowledge of the art of frame bridge building, and spans of 306 ft. at the commencement of the 19th century appear bolder than 1,200 ft. in our days. We can learn by studying Finley's plan how the neglect of his well-founded directions caused many disasters to suspension bridges.

It is astonishing how few understood him. Instead of keeping the stiffening continuous beams, and instead of proportioning the same according to the spans and loads of the bridges, it was believed to be an unnecessary weight and increase of cost of bridges ; and instead of adapting great deflections of cables or chains, it was believed to be a better arrangement by taking flat arcs, and deflections equal to $\frac{1}{15}$ of the spans, whereby the cost of bridges became nearly double as great as before.

Till the year 1801, according to Finley's patent, 8 bridges had been built in the United States, and there have been added 40 others between the years 1801 and 1808. The largest of all was the Schuylkill chain bridge, of 306 ft. span.

It is not uninteresting to know the names of some of the first buildings of this kind.

The Potomac Bridge, near Washington, had 130 ft. span, its floor being 15 ft. wide ; the Cumberland Bridge, in Maryland, had the same span ; the Brandywine Bridge, near Wilmington, was built with 145 ft. span, and a 30 ft. wide floor, and 2 other bridges were built of 120 ft. span each, at Brownsville, in Fayette county, in the State of Pennsylvania. A bridge across the Merrimac, 3 miles from Newburyport, in the State of Massachusetts, carried out by an engineer of the name John Templeman, of the District of Columbia, is more particularly described, and is one of the most interesting buildings in the history of bridges. The span of this bridge was 244 ft. ; the abutments, 47 ft. long and 37 ft. high, were made of good masonry. The 2 roadways, of 15 ft. width each, were strong enough to allow for the passage of horses and carriages, whatever their speed. Ten chains, each 576 ft. long, were made to bear 500 tons with perfect security. Three of the chains were fastened on each side of the bridge, and 4 in the middle. "The railing was stout and strong," a construction, which "contributed much to the stiffness of the floor." Thomas Pope himself calls it a wonderful structure, describes the railing as contributing much to the stiffness of

the floor, and states that Templeman's talents and improvements had earned for him a great reputation as engineer of such work. He also reported that the motion of the floor of the Merrimac bridge was "*very little perceptible*, whatever the *speed of any kind of traffic.*"

The bridge across the Lehigh, built in the year 1815, near Northampton, in Pennsylvania, consisting of two whole and two half spans, 475 ft. long, bearing two tracks for carriages and two 6 ft. wide footpaths, was the *first mentioned* suspension bridge of more than one span.

The *application of wire for suspension bridges* is also an American invention, for the first wire-bridge was built *before* the year 1808, at Philadelphia, across the Schuylkill river, with a span of 408 ft. I found in the book on wire-bridges, by the French engineer, Seguin, published in the year 1824, that a report on the American canals, written by Mr. Galatin in the year 1808, and copied in a French book from the year 1820, mentioned the wire-bridge at Philadelphia. The same bridge is also described in the "Bulletin de la Société d'Encouragement," in the year 1816.

According to these notices, the existence of the American wire suspension bridge was well known in Europe a long time before the first regular suspension bridge was built there.

Pope's book was well known in France, and Seguin, as well as the famous French engineer, Navier, made use of it. Finley's important invention, in connection with Templeman's improvements, as well as Pope's book, and the wire-bridges built in this country, were known in England by Samuel Brown and others in the year 1814, and it is most probable were known in France, for the brothers Seguin, French engineers, seem to have been in England, and Navier especially was sent there to study suspension bridges.

At that time a Frenchman of the name of Poyet proposed a kind of stay-bridges, consisting of high wooden masts as towers, from the tops of which were starting many stays to both sides, supporting the floor.

But the English engineers were the first who proposed and applied stays for suspension bridges, in connection with cables, as well as without them.

The first of these bridges was built by Richard Lees, at Galashiel, across the river Gala, in the year 1816, of a span 112 ft.; it was like the 2 following, a wire-bridge. The bridge at Kings-Meadow, across the Tweed [span 110 ft.], was built in the year 1817, and another structure, at Thirlstone Castle, 125 ft. long—both with stays. At Kelso, on the Tweed, a bridge of 300 ft. span was built for carriages—the roadway 18 ft. in width. A bridge at Dryburgh Abbey, with stays, was 260 ft. long, and very movable; so much so, that 4 persons could shake it so as to break one of the stays. In the year 1818 a wind destroyed the whole structure. Rebuilt according to Finley's system, provided with strong longitudinal beams, strong railings and anchors, like those at Niagara bridge, resisted the obnoxious motion. Especially is it stated that the *railing resisted all upward movements.* The use of anchor-chains, to prevent side and upward movements of the floor, is, therefore, already very old, and Sir Samuel Brown often made use of them.

The bridge at Dryburgh is interesting in another reference, as it is the first wherein the chains were convergent in middle of the span. At the towers of this bridge the distance apart of the cables was 12 ft., and in the middle of the bridge it was only 4 ft.; the object being to reduce the side motion. But the engineer, Stephenson, already observed that he preferred to keep the parallelism of chains, and rightly, as I hope fully to convince you in a future communication.

A great many of the stay-bridges broke down, and after many sad experiences, the use of stays has been entirely rejected by English engineers, notwithstanding they have been reintroduced into this country.

Navier saw different bridges built by Brown in England, and he describes the action of the stays in aiding to support the floor; others were introduced horizontally, but inclined to the longitudinal axis of the bridge, to reduce the side motion, and he criticised sharply the combination of stays with suspension rods and chains or cables.

The use of separate tension cables attached to the 2 towers, working horizontally or verticallyagainst the action of the wind; the application of pendulums to support the cables on the pillars, allowing expansion and contraction of cables, are

ideas of the famous engineer Brunel. These applications are made at Brunel's bridge on the Island of Bourbon, and are copied at the suspension bridge across the river Meuse, at Liege, in Belgium, and at the Alleghany bridge near Pittsburg.

Telford, the engineer of the Menai Straits suspension bridge in England, as far as I can learn, added the improvement of saddles on rollers, supporting the cables or chains, to allow for the movements in case of change of temperature. The railing of this bridge was proposed 6 ft. high, the span being 560 ft.

I have mentioned that by the French Government, in the year 1821, Navier was sent to England to study the existing suspension bridges, and to report on the same. He collected the different historical notices, described Finley's and the English bridges, and gave the theory of movable suspension bridges in his classical book, published in the year 1823. The curve of the suspension cables when loaded, Navier first regarded as parabola, rejecting the complicated older formulæ as given by Jacob and John Bernouilli, Huyghens, Euler, and others. It is to be regretted that this celebrated and highly scientific man overlooked the influence of wind acting from below on the floor, and thus becoming the most dangerous element to destroy suspension bridges. Indeed, Navier's theory and his reputation contributed much to the false judgments about Finley's improvements, and caused the error of introducing *small deflections* and of omitting the *American longitudinal beams and railings*, these important stiffening elements, which, in the right proportions, are inseparable from any good suspension bridge.

Finley expressly advocated the construction of *platforms of one piece*, but Navier and his followers supposed a *perfectly movable floor*. Finley applied $\frac{1}{7}$, Navier $\frac{1}{12}$ to $\frac{1}{15}$ of the spans for deflections. Finley prevented the undulations by his stiff platform ; Navier believed he could prevent greater deplacements by flat catenaries. This is the great antithesis of these two celebrated engineers, and every scientific bridge builder must concede that Finley stood much nearer to the perfect solution of this problem than Navier.

But notwithstanding, Navier's book was of great value to science, and he opened for investigation many interesting questions.

Navier paid attention to the effect of change of temperature on suspension bridges, and after having examined the use of rollers on the towers, he gives some hints about the effect of the same forces on the platforms, which he supposes to be movable. His own words in this respect are :

"By applying continuous longitudinal pieces in the platform of the bridge, it will be necessary to compound these pieces of parts connected by *joints*, which *leave a little freedom*, so that the adjoining parts *can slip* on the others, where the *heat* is lengthening the same."

But it is not to be understood that Navier meant to apply such slip-joints to the chords of a truss, for in our climate such a truss would not begin to work before it was bent to deflections equal to about $\frac{1}{60}$ of the span. Hence, it follows that if such a truss with slip-joints were applied to a suspension bridge, it would not work at all, but merely act as a dead weight.

In the same classical book, Navier describes the suspension canal-bridge, built by Count Chabrol in the department of Puy-de-Dôme, in France, the length of which was 650 ft., and he gives calculations and plans of a project of this kind. These ideas and plans have been applied by constructing the Pennsylvania canal-bridge for spans of 160 ft.

The first suspension bridge on the continent of Europe was built in the year 1823 at Geneva, in Switzerland, by Colonel Dufour. If was a wire bridge.

In the year 1824 the elder Seguin published the first edition of his work on wire bridges ; a book important in many respects, giving many new ideas and improvements.

There the utility of the stiffness of the platform of suspension bridges was not overlooked, as was done by Navier and the English engineers. On the contrary, the meaning and the importance of stiff railings as well as of longitudinal beams was fully appreciated.

I must not omit to translate a portion of this work, throwing light on the fact, that James Finley and Templeman are to be regarded as inventors and improvers of suspension bridges with stiffened floors,

rejecting all later pretensions and claims of this kind.

In the aforesaid book is to be found :

"One of the greatest inconveniences of suspension bridges are the vacillations arising from moving loads of any considerable masses. To prevent these, there should be employed all possible means affording rigidity ; the very best of all existing of which I know is the arrangement of *strong trusses as parapets of the bridges.* These have to consist of *long pieces of wood* forming the *frames*, and of wooden *Andrew crosses* put together at *right angles.* The connections of the different pieces should be made by *iron bolts*, piercing the *frames or chords between the joints of the diagonals*, allowing any desired tension and great rigidity."

Further Seguin says :

"The first quality of the floors or platforms of suspension bridges is to have as much rigidity as possible, and to obtain it care is to be taken to fasten together the different parts, so as to get a continuity preventing any separation. It is customary to attach the suspension rods *to* cross bearers which are supporting the floor itself, but it is possible as well to apply longitudinal pieces to support the cross-bearers, and it seems to me to be far preferable to establish in all cases longitudinal flooring before cross-bearers. The longitudinal pieces had to be of the greatest possible dimensions, their joints to be well connected to avert those horizontal movements, which are consequences of the deficiency of continuity in the floor.

"*The Americans had adopted ¼ of the spans for deflections of cables. This disposition, being very favorable in reference to solidity, is inconvenient in regard to deplacements, which become always the less the more the deflection of cables is diminished. But the Americans have neutralized that inconvenience by adding to the floors great masses, and using strong railings, to increase the rigidity.*

Concerning the said masses, Seguin meant evidently Finley's longitudinal and continuous beams, laid on the cross-bearers; the weight and action of which reduced the side motions caused by wind, and which had, besides this effect, the more direct object which Seguin mentioned before, but did not understand fully. Navier's influence on Seguin is evident already.

The brothers Seguin introduced the method of boiling the wire in oil, thus giving a good coating as a preventive of rust. But they observed that the wire, after the process of boiling, lost a portion of its strength, an observation which is confirmed by newer and very minute experiences of reliable men.* Indeed, the temperature of boiling linseed oil is at 600 deg. Fahr., which is the same temperature required to soften steel, at which that dark-blue color, so characteristic of the tempering of steel, is observable.

The method of covering the chains with white instead of any other color, as was Finley's practice, is first mentioned in the description of the Hammersmith bridge in England. The same Hammersmith bridge, as seen in the year 1854, was stiffened horizontally by cast-iron beams, suitable chords and diagonals, and the vertical movements were prevented by strong railings. This was perfectly sufficient for common traffic, and the Hammersmith bridge was celebrated for its good proportions and strength.

Many bridges of this time suffered by gales of wind; many of Brown's structures, and generally those near the sea, and more especially those constructed with stays, were destroyed entirely; others badly damaged. Telford's Menai bridge, for instance, was extensively injured, and the engineers fell into the great mistake of preventing the undulations and motions, caused by wind, by increasing the dead weight of the bridge itself. The floor of the Menai bridge has a weight of 97 lbs. per superficial square foot. But the evils of this system soon produce a change in the opinions of the engineers, and it was the engineer Rendel, to whom was confided the repair of the suspension bridge at Montrose, who was induced to apply a good method of stiffening the floor of suspension bridges. Though undoubtedly Finley and Templeman are to be regarded as the first constructors of stiffened suspension bridges, as we well know, and as Rendel's method is merely one of its applications, yet the ideas in that time were disturbed to such a degree, that he is to be regarded as the true reformator of suspension bridges, and as the man who again brought to clear understanding the idea of longitudinal beams

* Experiments by Professor Karmarsch and Engineer Brix, in Prussia.

and trusses reaching from one end of the bridge to the other. Rendel also condemned more decidedly the use of stays, and proved by fact the truth of his judgment.

This bridge of Montrose was built in the year 1825, by Samuel Brown, its span being 432 ft., deflection of cables equal to 42 ft., and width of floor 26 ft. In the year 1838 the platform was destroyed by a heavy gale, and in the year 1840 the chains gave way with a load of 700 men on the floor, whereby a considerable loss of life was caused.

Rendel, in his report, says :

"In the anxiety to obtain a light roadway, mathematicians, and even practical engineers, had overlooked the fact that when lightness induced flexibility and consequently motion, the force of momentum was brought into action, and its amount defied calculation.

"The author has long been convinced of the importance of giving to the *roadway of suspension bridges the greatest possible amount of stiffness in such a manner as to distribute the load or the effect of any violent action over a considerable extent.* The platforms of large bridges in exposed situations are acted upon in so many different ways by the wind, that he had *an objection to the use of stays or braces to counteract movements which ought rather to be resisted by the form of the truss-structure.* Holding such opinions, he determined to adapt a *framing, which, although connected rigidly in every direction, should nevertheless be simple, composed of two parts, capable of being easily renewed, should distribute its weight uniformly over the chains, not be subject to change from variation of temperature, and not augment the usual weight of suspended platforms.*"

According to these principles, which are embraced entirely in the old American inventions, but more defining the same, Rendel repaired the Montrose bridge in the following way : "Instead of cast-iron cross-bearers, he adopted wooden joists 13 ft. by 3½ ft., bolted together and trussed with a round bar of 1¼ in. diameter; every 6th beam had a deep trussed frame on the under side, so as to give great stiffness above and beneath the cross-beams ; on each side of the carriageway were bolted 2 sets of longitudinal timbers, 4 in each set ; they were further united by cast-iron boxes at intervals of 10 ft. A curb of timber, 11 in. by 6 in., was attached to the ends of the cross-bearers, and extended the whole length of the platform. To add to the stiffness afforded by this construction, the author caused to be passed through the spaces between the pair of longitudinal beams, a series of diagonal truss-pieces of timber, 6 in. sq., with the ends stepped in the cast-iron boxes, which at every 10 ft. grasp the beams. On the other end of these diagonal truss-pieces, an iron screw bolt, 1¼ in. diameter at every 10 ft., and a contrivance of wedges in the cast-iron boxes, enabled any degree of tension to be given to the framing. The roadway was thus stiffened by 2 of the strongest kinds of framing in parallel lines, dividing the carriageway from the footpaths."

This truss-work, with the perfect understanding of the working momenta, was expressly made to resist flexures upward as well as downward, an arrangement omitted in one of the greatest existing constructions.

The requisite horizontal stiffness was obtained in the following way : The carriageway was formed of 4 thicknesses of Memel planks, the 2 lower layers, each 2 in. thick, were placed diagonally with the transverse beams crossing each other so as to form a reticulated floor, abutted against the longitudinal beams. They were firmly spiked to the beams and to each other at all the intersections, and upon them was laid and spiked a longitudinal layer of planking 2 in. thick. Each layer was closely jointed and caulked, and the upper one was laid in a mixture of pitch and tar ; a composition of fine gravel and sand, cemented with boiled gas-tar, was laid over the whole, to the thickness of 1 in., forming the road track."

The absence of Brunel's counter-chains and of Brown's counter-stays, and other unnecessary and even dangerous furniture, is to be regarded as highly commendable.

"The whole formed a compact mass of braced wood-work, the diagonal planking giving the horizontal stiffness, and the two trussed frames insuring the vertical rigidity."

It is interesting to know the weights of this structure, as important concerning the art of building suspension bridges with stiffened floors.

The weight of the roadwork was	131 tons.	Per running ft. 0.53 tons,	
" of cast and wrought iron	37 "		
" of suspension rods	21 "		
" of fencing (wrought iron)	9 "		
" gravel concrete	30 "		
Total	228 tons.		

or 47½ lbs. per superficial sq. ft., for the entire roadway. Subtracting the gravel concrete, it is 41 lbs. Before the bridge was stiffened, the weight was 44 lbs. per sq. ft.

The bridge has borne, without injury, heavy gales, as could be foreseen, and the stiffness has given confidence in the strength to all who have examined it.

The English engineers agreed with Rendel, and the engineer Vignoles eulogized this excellent communication for the practical conclusions which it contained. "He found it not difficult to foresee, that by carrying out the system of *adopting well-trussed framings* to the platforms of suspension bridges, *sufficient rigidity* would have been obtained for *locomotive engines and carriages on railways* to traverse rivers or ravines by means of these bridges, instead of the costly viaducts or heavy embankments; and Mr. Rendel saw no difficulty in giving any required amount of rigidity to the platforms; it was only necessary to increase the strength of the framing, to enable the roadway to bear with perfect safety the passage of an engine and a train of carriages.

In the mean time the wire bridges found a favorable reception in France, which is full of admirable structures of this kind, and the French engineers brought the manner of constructing cables to the high degree of perfection of our day.

After the preceding introduction of wire bridges in England and Switzerland, the brothers Seguin constructed the first wire suspension bridge in France, in the year 1824. All the existing methods of splicing wire, of bringing up the cables, have been studied, and theories of great mechanical value have been invented.

The cables were first made on land and then carried on the towers by machinery, but soon the French engineers began to build them on the towers themselves. Very perfect methods have been employed, securing all possible equality of tension in the single wires; and as greater perfection always requires more time and trouble, these methods are more expensive than those of a later origin, which, shortening a little the time of construction, are not securing the same equality throughout.

Now, the time to make a wire cable of 1,600 ft. length, is about *one year*, which involves *a great loss when we consider that steel chains can be obtained cheaper, much more secure, much lighter and better*, than any wire rope can be, and by the use of which *the time for building* suspension bridges is *considerably reduced.*

Such a steel chain bridge was built in Vienna in the year 1829, by the Austrian engineer Mitis. It is praised in all reports as a strong structure.

The wrappings of the French cables are made at intervals of about 1 ft.; in later times the wrappings have been made continuous.

In the year 1831 the French engineer Vicat, in his report on the suspension bridges across the river Rhone, described his method for building wire bridges in place, directly on the towers and abutments, a method which, essentially in the same manner, was copied by erecting the Niagara and Cincinnati bridges. This method is described as follows:

"The towers and abutments of a suspension bridge being finished, the points of attachment ready to receive the cables, and supposed that a number of double wires of equal lengths, forming circuits, are wound on different reels, these *wires are drawn from one pillar to the other by means of a thin endless rope*, like the guide-rope of a flying ferry, and moved like the *chain of a chain-pump.*"

By this method Mr. Vicat proposed to make and suspend cables, with less cost, with fewer workmen, and in shorter time than before. He said it was not difficult to reduce *the number of cables to two*, if it was desired; whereby the surface exposed to oxidation would be diminished; the tension of the single wires would be uniform, whatever the thickness of the cables; the apparatus for elevating the cables be simplified, and the greatest possible spans would be admissible.

More details on this subject can be found in the article on bridges across the river Rhone in the French "Annales des Ponts et Chaussées," 1831, volume first.

Mr. Chaley, the engineer of the celebrated suspension bridges at Friburgh, in Switzerland, worked out Mr. Vicat's method, and often had occasion to apply it. He, according to the same method, built the second suspension bridge at Friburgh, in Switzerland; further, the bridge "de la Charité," across the river Laire, a suspension bridge in Paris, another at Percy, in the Jura mountains, and the bridges at Cormery, across the Indre, and of Beaumont, across the Sarthe, in France.

Vicat's method was further employed at a bridge at Tours, in France, for transporting materials. Interesting details are found in the "Annales des Ponts et Chaussées," year 1841.

Other methods for constructing the cables of suspension bridges directly on the towers and abutments, is that of the French engineer Le Blanc, constructor of the splendid bridge at Roche-Bernard; and, after him, that method introduced by the French engineer Le Clerc, the constructor of the suspension bridge at Lorient, across the Scorff. The anchorage of these bridges (the first is of 643 ft. span, the other 610 ft.) is interesting, as the cables form one continuous belt, laid around the abutments in suitable vaults, allowing free circulation of the air, as well as to repair the painting of the wire from time to time. The two cables, at both sides of these bridges, have the *same deflections*, an arrangement which is not objectionable. (The descriptions can be found in the "Annales des Ponts et Chaussées," 1850.)

The French methods and designs have been used in our country; especially the method of constructing the cables directly on the towers, in the year 1844, at the Alleghany suspension bridge, near Pittsburgh, and Vicat's invention was a little, but not essentially, modified at the construction of the Niagara and Cincinnati suspension bridges by Roebling.

A picturesque suspension bridge is that at Cubzac, across the river Dordogne, in France, with five continuous spans of 363 ft. each, the towers being constructed of iron (iron towers 82 ft. high; total height of towers above low water, 126 ft.).

Iron towers also are used at the chain bridge at Seraing, in Belgium, and at the chain bridge at Muehlheim, on the Ruhr, in Prussia.

Since the accident of the wire bridge at Angers, in France, in the year 1850, many of the wire bridges in Paris have been replaced by truss and arch structures, and a law is introduced directing tests of wire bridges from time to time. During such a test in the year 1861, the suspension bridge at Mirabel sur L'Eggues broke down, the cable having been destroyed by rust in the interior.

The elder Seguin, in the year 1840, had an opportunity to apply the old American method of stiffening suspension bridges, which he appreciated highly, as has been demonstrated. *He was the first man, at least in Europe, who built a suspension bridge for railway purposes, and with full success.*

His work was an auxiliary suspension bridge across the Soane river, built in the year 1840, when some spans of the wooden railway bridge were swept away. The two spans of his bridge were 137.5 ft. each, the deflection of the cables was $16\frac{2}{3}$ ft., girders $8\frac{1}{2}$ ft. high, composed of wooden beams 9 in. by $2\frac{1}{2}$ in., and chords of 13 in. by $6\frac{1}{2}$ in., connected with the longitudinal beams of the floor by screwbolts, and kept in vertical position by braces, were to stiffen the floor vertically. The three cables on each side were connected by numerous ligatures. This new bridge was reported to have been *as stiff as the former truss bridge*, and was used as a railroad bridge during four years, with perfect success, and then the remaining wooden frame bridge as well as the suspension bridge were replaced by a stone structure.

This bridge also had neither stays to support the floor, nor stays to add for horizontal stiffness.

Our vice-president, Mr. Julius W. Adams, kindly showed me a plan of a stiffened railroad suspension bridge across Kentucky river, at Frankfort, which he passed over in the year 1852. It had been built some years previously, but precisely when, or by whom, he was unable to ascertain. It is possible that it was built before Seguin's structure. Besides this, it had also no stays. The spans of this stiffened suspension bridge were 100, 261, and 200 ft., the lattice girder was 6 ft. high, the distances of suspension rods and likewise of the cross-bearers equal to 3 ft., and floor with girders had the calculated weight of 930 lbs. per lineal foot.

In the year 1845, the Austrian engineer,

Schnirch, who built the well-known suspension bridge at Prague, proposed a new system of suspension bridges, the curves consisting of two pairs of parallel chains, one above the other, and both connected by triangular trussings. At these bridges the chains themselves represent a stiff inverted arch, and are to be calculated only as such. A bridge of this kind, before Schnirch had occasion to introduce his system in practice, was carried out in Switzerland, across the river Aar, near Aarau, but the distance of the chains was too small to be considered as sufficient.

Schnirch's plan was carried out for two tracks in Vienna, in the year 1861, to bridge a canal of the Danube river. As Schnirch's plan is of so old origin, and an ingenious invention, and as the suspension railroad bridge in Vienna is until this day the best though not the longest stiffened suspension bridge, I will proceed to describe it.

Two parallel chains on each side, consisting of alternately eight and nine link plates each, are placed at a distance apart of 4.1 ft. The trussing consists of a single triangular system, the diagonals being 6.4 ft. long, the links of the chains are 10 ft. long and 6 by 1.35 in. and 6 by 1.16 in., respectively ; two pairs of chains, in a distance of 31 ft. from centre to centre, limit the floor sideways ; four longitudinal trusses of wrought-iron, consisting of uprights and crossing diagonals are made to stiffen the floor and to offer suitable points of attachments to the suspension rods, at distances of about 5 ft. The suspension rods themselves are made adjustable. The longitudinal trusses are 2.5 ft. high, and represent likewise the chords for a horizontal trussing, the uprights of which are the cross-bearers, iron girders of 2.5 ft. height, and the diagonals are strong iron bars, fastened by rivets.

The span is 252 ft.; anchorage, architecture of piers, and performance are entirely successful.

Though this bridge has no great span, it is to be regarded as the best and most complete, in point of principle, of all existing suspension bridges. I therefore believe it is an act of justice to give to a man of the originality of Mr. Schnirch the honor which he has a right to claim.

During this time the American engineers, occupied in improving the wooden truss bridges, did not forget to appreciate suspension bridges, and that they constructed the greatest spans, is well known. I mention the former Niagara bridge, of 1,042 ft. span ; Ellet's Niagara bridge, of 760 ft.; and the unfortunate Ohio bridge, at Wheeling, of 1,010 ft. span. The latter, without any kind of stiffening, succumbed to a heavy hurricane, in the year 1854. Stays would not have prevented this accident, for, under the same circumstances, stays were rejected at an early day of this century.

At the time when the Britannia tubular bridge was to be built, R. Stephenson proposed a stiff suspension bridge, in form of an iron tube, suspended by chains. Many and costly models were built, as at this time no theories existed either of truss or of suspension bridges. The tubes in these models were made stronger and stronger after every experiment ; and, lastly, the chains were no longer necessary and were dispensed with, and the iron tubular bridge was the result.

It is plain that the Niagara railroad bridge is the direct application of Stephenson's plan.

This work, as well as the Cincinnati bridge, are sufficiently known, and therefore I do not consider it to be necessary to describe them, nor to demonstrate that they are to be appreciated as great works of American enterprise and boldness, but exhibit nothing commendable in the way of *invention.*

Before finishing this short sketch of the history of suspension bridges, I have still to mention that the third possible arrangement to stiffen a suspension bridge was carried out in London in the year 1862 by the engineer Barlow, who bridged the Thames by 3 single spans of 280 ft. each. This work is named the Lambeth bridge.

The said system consists of cables, horizontal beams, and uprights, with diagonals between the cables and beams, so that these represent the chords of the truss-work. This arrangement is the most objectionable of the 3 possible manners of stiffening suspension bridges.

The detailed construction as furnished by Barlow is unnecessarily complicated, and the tube, this favorite monster of English engineering, is not forgotten.

Over 3,000 men are employed in the construction of the N. Pacific Railroad.

SOME OF THE METHODS OF SHEATHING IRON SHIPS WITH COPPER AND ZINC.*

By MR. W. FORSYTH BLACK.

From "The Engineer."

The author first referred to the very serious evils of corrosion and coating of the hulls of iron vessels, and the failure hitherto of compositions and paints to obviate these grave disadvantages; and described the results of Admiralty trials in this direction. After showing the loss to shipowners from diminution of speed, and the great cost incurred by them for frequently docking their ships, he proceeded to describe the plan of sheathing iron vessels with copper invented by M. Roux, captain in the French navy, whose process has been applied to several of their armor-plated ships. By this method, while great care is taken in the insulation of the hull of the vessel from its copper envelope, a very ingenious means is adopted for securing the sheathing to the plate of the ship. Holes are bored in rows at about 2 in. apart of a depth of $\frac{7}{32}$ in., and a recess is formed of a greater diameter than the hole by means of a spring rose bit. The rivets are formed with a base, a collar in the middle, and a head, and a hollow set-tool is employed for riveting them. To fasten one of them in its place, the head is inserted in this set tool, which bears on the collar, and the base placed in one of the holes. The head of the set is struck with a hammer, and the base of the rivet, which is of a semicircular hollow section at the bottom, fills up the recess in the hole, and is firmly fixed and the head projects. When all is prepared the copper sheets are laid on and the projected heads of the rivets are riveted down. There is however, always, he considered, danger of the insulation of the copper sheathing failing through some accident, if not from other causes, besides the drawbacks to its use on account of the cost of application and material. The author went on to describe what had been done in the direction of applying some other kind of sheathing which would not be dangerous to iron by being brought into contact with it. He gave an account of the experiments which had been made by the Admiralty and others to test the efficiency of covering iron plates with zinc, and which had been proved very satisfactory, especially where no insulating medium had been interposed between the two metals; this result might have been expected, he showed from the position of zinc to iron in the electric scale of metals; just as iron is certain to be destroyed by contact with copper when salt water can reach both so placed, so is iron preserved by contact with zinc under the same conditions. He then described Mr. Daft's proposed method of building ships with a special view of providing a simple means for the attachment of zinc sheathing. That gentleman proposes to rivet all the plates of the vessel directly to the frames or ribs, and that the joints shall be made on the lap principle throughout, but in such a way that a flush surface shall be obtained. This he effects by leaving a space along the sides and ends of the plates equal to their thickness. After the plates have been caulked against the joint straps from outside, and then against the plates from inside of the vessel, he fills up the spaces with strips of compressed teak, to which he secures the sheathing with iron or zinc nails (by preference the former) of such a length, that on meeting the iron at the back of teak strips the points turn round and are clinched. He concluded by describing plans for applying zinc sheathing to ships built on the ordinary in-and-out strake system, by filling the spaces between the out strakes by teak planks equal to their thickness. By this means a flush side is formed, and the sheathing can readily be nailed on, and the nails clinched as shown above. He also suggested that the raised holes of M. Roux's system, and zinc rivets, might be employed for zinc sheathing, instead of the methods indicated.

* Abstract from a paper read before the Civil and Mechanical Engineers Society, London.

The annual account of coal mined and shipped in Nova Scotia has just been issued by the Chief Commissioner of Mines. In 1827, 11,491 tons were shipped, and in 1869, 578,062. The total production in the 43 years was 9,023,701 tons.

GUNPOWDER.

From "The Mechanics' Magazine."

A late number of the "Westminster Review" contains an elaborate and ably written article on gunpowder, from which we cull the following facts for the information of our readers.

Improvements in the manufacture of gunpowder have not kept pace with the advance made in the manufacture of guns. Indeed, all military manufactures have been improved within the last few years to an unexampled extent, whilst the production of gunpowder, so far, at least, as the proportions of its ingredients are concerned, remains almost exactly as it was many years since. Some progress has, however, been made in the methods of preparing and purifying the ingredients, whereby the deadly composition is rendered more suitable for the particular purpose for which it is employed. As in the manufacture of guns and iron-clad ships so it is with gunpowder—scientific knowledge must be brought to the aid of practical experience. Hitherto the knowledge of the chemist has not been brought sufficiently to the aid of the gunpowder manufacturer, and hence the improvements made by the latter have not been on a level with those of the artillerist or the manufacturer of small arms. It is owing to this comparative paucity of scientific knowledge that such small strides have been made in the improvement of the fiery compound. It appears that the cause of this slow advance rests, mainly, with the manufacturers. There is plenty of chemical knowledge to be obtained in this and other countries; but that is of little avail without the conviction of the necessity for its utilization on the part of the manufacturers of gunpowder. The absence of this conviction on their part has been injurious in many ways. It has not only indirectly increased the expense and delay in the improvement of guns, but has been the cause of many explosions, resulting in great loss of life and destruction of property. But these times are passing away, and gunpowder manufacturers are beginning to recognize the necessity of bringing chemistry to their aid.

It has until recently been the chief aim of the manufacturer to produce a strong powder, but it was essential that the powder should be clean—or, in other words, should leave but little residuum to foul the gun. In attaining cleanliness a strong powder was obtained, and as guns were enlarged in calibre the charges of powder were increased, till at last the problem became, How to make a gun strong enough to resist the charge of the required strength of powder? But this is not the case now; powder is now made to suit the guns for which it is intended instead of making guns to stand the force of the powder. Two great objects have thus been gained—a diminished pressure on the gun and an increased initial or muzzle velocity.

We shall entirely pass over the elaborate description of the manufacture of powder generally and the various alterations and improvements it has undergone during the past few years, given in the "Westminster Review;" and we must also leave unnoticed the legislation which has taken place with the view to regulate the making, keeping, and carriage of gunpowder and other compositions of an explosive nature. We may here just stay to record that the writer in the "Westminster Review," when speaking of the liability of "press-houses" to explosions—and particularly of the press-house explosion at Waltham Abbey—says: "We believe it is an ascertained fact that copper and copper can be made to produce a spark, but gunpowder makers are slow to believe it." Now with reference to this observation we may state that so long ago as 1859, when writing in the pages of this journal of the explosion at the Hunslow Gunpowder Mills, we said,* "with gunpowder copper as a metal has, from the time of Roger Bacon been supposed to be friendly, and men have not doubted that the former would patiently submit to be knocked about by the latter with the greatest unconcern; yet after such a fact has been almost universally accepted as beyond dispute, experiments in France and Austria incontestably prove that, under special circumstances, copper is as liable to produce its ignition as iron.

* Vide "Mechanics' Magazine," April 8, 1859, p. 230.

Indeed, at the accident at Hatton, about a year ago, a spark was seen to escape from the copper tool used by one of the men. And now we have iron rollers substituted at the Hounslow Powder Mills in lieu of stone, as iron is considered to insure an additional safety from accidents." We are of opinion that if gunpowder manufacturers have not yet settled this point beyond all grounds of dispute, it is time they had; their not having done so would go far to prove the justice of our foregoing observations.

It is, however, more particularly to the manufacture of "pellet" and "pebble" gunpowder that we wish to refer. Mr. Cardwell, in his speech to his constituents at Oxford on the 2d inst., said that powder was not like wine, that it would not improve by keeping, and that we had enough in store for the average consumption of several years to come. "But," said he "there are changes taking place in ammunition and guns which materially affect the question of powder, and this applies especially to the kind of powder recently introduced for heavy guns. These improvements have been made in powder for heavy guns during the time I have held office. Only in May last a particular kind called 'pebble' powder was approved, and we immediately set to work to adapt our machinery for the use of pebble powder, and are most desirous of getting all the best pebble powder we can get at a fair price as rapidly as possible." We hope that Mr. Cardwell's good intentions will be carried out.

When charges of 50 lbs. of powder were required, it was found that the severe strain caused by the combustion of "large-grain rifle" (L.G.R.) was very injurious to the guns. It was comparatively detonating in its action, and it has been asserted that "no other guns in the world have ventured to employ it." It therefore became a vital question whether a powder could not be made which, while as powerful or more so in the direction of the shot, should exercise a less destructive pressure upon the gun. A powder having its grains of a uniform size and shape, of a uniform density and slow in its action, would, it was thought, meet all the requirements, and "pellet" powder was first provisionally adopted. The "pellets" are procured in the following manner:—The broken millcake is placed in cylindrical holes, into which closely fitting punches are forced by hydraulic pressure, so adjusted that the required density can be obtained. The powder is then glazed, if thought necessary, and dried in the usual manner. The particulars as to the size, etc., of these "pellets" are as follows:—

Range of density of the pellet	1.65 to 1.7.
Diameter of pellet	0.75 in.
Depth	0.485 in. to 0.495 in.
Diameter of cavity, or indentation in end of pellet	0.2 in at top. 0.15 in. at bottom.
Depth of cavity or indentation in end of pellet	0.25 in.
Range in weight of the pellets	85 gr. to 95 gr., *i.e.* about 75 to the pound.

The pellet may, of course, be made of different forms. A cylinder with both ends flat is as easy to make as one which has one end flat and the other indented. Lately, another kind of pellet has been adopted; this is a cylinder with both ends convex. A large quantity of this powder has been manufactured in England for continental use.

The results obtained by pellet powder far surpassed those obtained by the use of L.G.R., but the difficulties in making it led to further experiments, and these resulted in the production of what is designated "pebble" powder, which may be said to consist of lumps rather than of grains, each lump being a rough cube having a side of $\frac{5}{8}$ in. The pellet form was abandoned, it is stated, because of difficulties in the manufacture; are the difficulties in producing "pebble," it has been asked, insuperable?

The advantages of pellet and pebble powders over L.G.R. are strikingly illustrated in the following table, which gives the comparative values of the three kinds of powder:—

Description of powder	Charge.	Initial velocity, per second.	Maximum pressure per square inch.
Large grain rifle	30 lbs.	4,324 lbs.	29.8 tons.
Pellet	30 lbs.	1,338 lbs.	17.4 tons.
Pebble	35 lbs.	1,374 lbs.	15.4 tons.

From this it will be seen that our guns have been subjected to a strain nearly double of that which they will henceforth undergo, while the muzzle velocity will be increased. In these experiments the gun

used was an 8-in. smooth bore, the shot being cylinders of iron weighing 180 lbs., having a diameter of 7.995 in.

After the gunpowder is finished it has to undergo various kinds of proofs. First, the "hand proof," by which its general appearance and freeness from dust are examined. Second, "flashing" on a glass plate, which shows to a practised eye whether the incorporation is complete, and whether the powder is likely to foul the guns when fired. Third, cubing or ascertaining the weight of a cubic foot of powder. A cubic foot of Enfield rifle weighs nearly 54 lbs., while L. G. and L. G. R. weigh 56 lbs. and 60 lbs. respectively. The "pebble" is not "cubed," but its density ranges from 1.70 to 1.82. The last proof is the firing. The old method was to place 2 oz. of L. G. or 3 oz. of L. G. R. in the chamber of a mortar, and fire a solid shot of 68 lbs. The distance this ball was carried was held to be a test of the strength of the gunpowder fired. Every gunpowder maker knew the system was utterly untrustworthy, and it was only tolerated because no better method was known. Now a different and scientific method has been devised, and our English gunpowder will, it is believed, be quite equal to its requirements. The old and clumsy "cube" is to give way to the mercurial densimeter, and the mortar must yield to Captain Andrew Noble's chronoscope or to the chronograph.

Little more than a year since the Navez-Leurs' electric-ballistric apparatus was thought to meet every requirement in the proof of gunpowder, but it was quickly superseded by the chronographs of Captain Schultz and Professor Bachforth. These only measure velocities after the shot has left the gun, while the chronoscope, invented by Captain Noble, measures the time which the projectile occupies in traversing any part of the gun to the one-millionth part of a second. This instrument is briefly described as follows: A series of six hollow plugs is screwed into a gun at intervals from the shot to the muzzle. Each of these plugs passes from the outside of the gun to the surface of the bore. As the ball, when the powder has been fired, moves by the first plug, it presses a cutter which separates a wire passing through the plug to the outside of the gun. This is repeated as the projectile passes each plug. Each of the wires so divided is the primary wire of an induction coil, and as each is divided an electric spark is flashed from the secondary wires on to a corresponding thin metal disc, the edges of which are covered with white paper coated with lamp-black. These discs, which are 36 in. in diameter, rotate at about the rate of thirty revolutions a second, or about 1 in. of circumference in the one-thousandth part of a second. This inch of circumference is divided by means of a vernier into 1,000 parts, thus giving readings to the one-millionth part of a second. As the electric spark is flashed out, it is received on the edge of its disc, and burns away the lampblack, leaving a white spot, from which calculations are made.

To determine the direct pressure exerted upon the gun, Rodman's pressure gauge, and an instrument called a "crusher," are in use. The former consists of a number of plugs fitted into the bore of the gun, each of the plugs being fitted with a knife-edge and a small piece of copper. The depth to which the knife is driven into the copper, registers the pressure at that part of the gun. The "crusher "gauge is similar in principle to the Rodman, but, instead of a knife-edge cutting into copper, a solid cylinder of copper is crushed by a piston, which is set in motion by the pressure of the gas. A testing apparatus shows the force required to effect a given compression. This "crusher" gauge gives results far more satisfactory than those given by the Rodman gauge.

The writer of the article in the "Westminster Review" concludes by stating that every little while the public is startled by an account of deaths by gunpowder, and that, although he does not think any legislative action will ever make the manufacture of gunpowder a safe trade, he believes that the appointment of two inspectors thoroughly acquainted with the nature and details of the business would do much to diminish the dangers which attend the public generally, not only from gunpowder, but from all other explosive compounds used for mining purposes, and their reports, presented from time to time, might form the foundation of a new Gunpowder Act, which, while it should interfere as little as possible with the rights of manufacturers, and place few restrictions

upon their trade, should make regulations for the guidance of the makers, the sellers, and the users of all explosive compounds, whether gunpowder, fireworks, gun-cotton, percussion caps, nitroglycerine, or dynamite.

ON THE ARCHIMEDEAN SCREW FOR LIFTING WATER.

By MR. WILFRID AIRY, Assoc. Inst. C. E.

From "The Artizan."

This communication was intended to supply information regarding the best form of the Archimedean Screw, and its effect when laid at different angles of inclination to the horizon. After suggesting that the previous neglect of this subject was probably owing to the mathematical and practical difficulties attending the construction of screws in the ordinary way, viz., with the threads at right angles to the surface of the core, the author stated that he had adopted another principle of forming the spiral threads, which would simplify the work of construction and produce a more efficient machine. This was to make the spiral threads on the natural and developable system. If an annular piece of card, or tin, be wrapped upon a cylindrical core, having its edge retained in a shallow spiral groove on the surface of the core, it would naturally take up a fixed and determined position, not at right angles to the surface of the core, but inclined to it; and inclined to it at an angle depending only upon the inclination of the spiral groove on the core. The chief advantage of this spiral thread was that it could be made of a single flat piece of plate, and no work was required except to cut out an annulus, which when wrapped upon the core, gave at once the spiral surface; whereas the threads at a right angle to the surface of the core could only be constructed approximately, by using a great number of small pieces. The developable threads also produced a more efficient machine than the threads of the usual form, as was shown by reference to tabular diagrams.

The first set of experiments was made with models of screws of different spiral angles (the "spiral angle" of a screw being the inclination of a spiral line on the core to the lines parallel to the axis of the core) having only one thread apiece, and the results of these experiments were given on the diagrams; but it was easily seen that every screw ought to have as many threads as ordinary workmanship and convenience would allow. This was also shown by reference to the results of experiment; and it was concluded that to allow of easy fitting, riveting, and examination, the width of the chambers for a large screw should not be less than 18 in. on the square. This condition was used to regulate the number of threads for the models for the second set of expeiments.

The second set of experiments was made on 6 models, whose spiral angles were 20, 30, 40, 50, 60, and 74 deg.; the number of threads being varied from 4 to 1. The models were successively inclined at different angles, and the water contained by each model in its different positions was measured by a measuring glass. These experiments formed the basis of the investigation, and it was deduced from them:

(1.) That the quicker the spiral, the flatter must the machine be laid to produce its best effect.

(2.) That screws of quick spiral angle, when laid at their best angle of inclination, delivered a far greater volume of water per revolution than those of slower spiral angle when laid at their best angle of inclination.

In order to ascertain the most economical form of screw, it was necessary to investigate the loss of power due to the internal friction of the water and the external friction on the gudgeons for each machine. This was done by calculation, and the results were obtained numerically for screws of certain specified size, lifting to a height of 10 ft. The frictional drawbacks thus obtained were applied to each machine when laid at its best angle of effect, and the efficiencies of the different screws were then calculated. The result showed that the machine whose spiral angle was 30 deg. was the most economical, but that the machine whose spiral angle was 40 deg. approached it very

closely. The best angles of inclination for these two machines were respectively 25 and 30 deg. to the horizontal. In the most favorable case, the useful effect of the screw appeared at 88 per cent., and it was concluded that, after making allowance for certain small losses referred to, the useful effect of a well-constructed screw should not be less than 85 per cent. Reference was then made, by way of comparison, to other machines commonly used for low lifts, viz.: suction pumps, centrifugal pumps, open Archimedean screws, scoop wheels, chain pumps, and Persian wheels; and the paper concluded by pointing out the various advantages of the Archimedean screw, more particularly as regards its durability, simplicity, and useful effect. The communication was illustrated by the series of models from which the results were obtained, and also by a screw, 5 ft. in length, constructed on the system of threads advocated by the author. A model was likewise exhibited, to show the improvements which might be applied to obviate the defects of scoop-wheels, as at present constructed and mounted.

TRACTION ENGINE RESISTANCES.

From "Engineering."

Lieutenant Crompton, "R. E," has lately published, in the columns of a contemporary, a somewhat remarkable paper on "The Properties of Elastic Tyres." We do not know Lieutenant Crompton, neither do we know to what title the letters appended to his name refer—for, in searching the "Army List," we have found but one Lieutenant Crompton in the Royal Engineers, and we have been informed that *he* is *not* the writer of the article we have mentioned; but we should judge, from the tone of his paper, that he is a great enthusiast in the matter of india-rubber tyres. In fact, his paper mainly consists of an enumeration of the vast advantages which, according to his ideas, attend the application of such tyres to traction engines, no notice whatever being taken of the numerous drawbacks by which the use of such tyres is attended. Our own opinions of india-rubber tyres we gave plainly in December last (*vide* page 425 of our last volume), and we have not since met with any reasons for modifying the views we then expressed—views which, we need scarcely add, differ to a most important extent from those of Lieutenant Crompton. It is not this difference of views, however, that has led us to notice Lieutenant Crompton's paper here. Many of the advantages of india-rubber tyres, so plausibly urged by that gentleman, are so entirely matters of his own opinion, and are so totally unsubstantiated by definite proofs, that it would not be worth while for us to waste time in arguing on them. But, in addition to these expressions of opinion, Lieutenant Crompton makes certain definite statements concerning the rolling resistances of engines and wagons mounted on rigid and elastic-tyred wheels respectively, and as he lays down these statements authoritatively, as if they were the results of actual experience, it may be worth while to criticise some of them. We are, of course, willing to admit that over rough and uneven roads the rolling resistance of elastic-tyred wheels will be less than that of rigid wheels (and if india-rubber tyres would last for ever, and if their cost was low, they might therefore be employed on such roads with advantage); but when Lieutenant Crompton informs us that on newly broken stone the rolling resistances of elastic-tyred wheels is 110 lbs., and that of wheels with rigid tyres 440 lbs., (!) per ton of load carried, we may be excused for making a few simple calculations to verify his results. The immediate result of these calculations has been to enormously increase our respect for Messrs. Aveling and Porter's steam road rollers. We always admired these machines, and considered them excellently adapted for the work they had to perform; but we never, until we read Lieutenant Crompton's table of resistances, appreciated their enormous power-generating qualities. A few figures will explain what we mean. Messrs. Aveling and Porter's rollers are capable of travelling easily over a newly-laid road at the rate of 2½ miles per hour, or 220 ft. per minute, and, according to Lieutenant

Crompton, the power which they expend in overcoming the rolling resistances would thus be $220 \times 440 = 96.800$ ft. lbs. for each ton of their weight. But the frictional resistances of the engine, gearing, and pitch chains, etc., may certainly be taken as absorbing 15 per cent of the indicated power, and thus the latter would have to be greater than that required to overcome the rolling resistances in the proportion of 100 to 85, or, in other words, the indicated power developed must amount to $\frac{96800 \times 100}{85} = 113{,}882$ ft. lbs. per minute, or 3.451 horse power, for each ton of the roller's weight.

Thus it follows that if—we say *if*, mind—Lieutenant Crompton's statements are correct, a 15-ton roller must develop 51.76 indicated horse power when moving at the rate of $2\frac{1}{2}$ miles per hour. Considering that Messrs. Aveling and Porter fit each of their 15-ton rollers with a boiler and cylinder, etc., of the dimensions of their ordinary 6-horse engine, such a result as that above stated is, to say the least of it, somewhat surprising, and it will probably lead most people to suppose that Lieutenant Crompton's table of resistances requires some revision. We may further direct Lieut. Crompton's attention to the fact that London 2-horse omnibuses, weighing, loaded, over $2\frac{1}{2}$ tons, are frequently drawn over a length of newly laid roadway at the rate of 4 miles per hour, and that thus, if his data as to the rolling resistance of rigid wheels is correct, each horse must, under such circumstances, "indicate" $6\frac{1}{4}$ horse power, and exert a dead pull equal to more than half his own weight! Probably he (Lieut. Crompton, not the horse) may find this "fact" in natural history interesting. Some of Lieutenant Crompton's other statements—such, for instance, as that on soft grass land the rolling resistance of rigid wheels is $3\frac{3}{4}$ times as great as that of wheels with elastic tyres, and that on such land rigid wheels "possess practically no adhesion at all"—we may probably comment upon hereafter.

THE ATLANTIC TELEGRAPHS.

From "The Engineer."

The two English Atlantic cables have now ceased to work for some months, and the French Atlantic cable is said to be stuttering. An American journalist has not scrupled to declare that the breakdown is a "judgment" upon the two cables, which have met the fate of Annanias and Sapphira, and for the very self-same reason, namely, that their statements were often considerably in advance of the truth. Every year since they were laid there has been a breakdown of one or other of the two cables, the stoppage of communication in each case arising from preventable causes; and we pointed out in this journal at the time the cables were being deposited in the ocean bed, that the present accidents to them must of necessity occur, and could be avoided. The precautionary measures we recommended would have cost little—in fact the expense would have scarcely been felt at all by the shareholders, and would have saved them their present enormous losses.

The early publications issued by those commercially interested in the projected Atlantic telegraphs gave vivid pictures of the smooth, oozy bottom of the Atlantic from Ireland to Newfoundland, saying nothing about icebergs and a rocky bottom; they also stated that the route along which the French Atlantic cable is now working was utterly impracticable, and worthless for telegraphic purposes. On sifting the evidence from independent sources, however, and on examining standard charts, we discovered that the cable would be exposed near Newfoundland to dangers arising from the grounding of icebergs, aud the rocky nature of the bed at that part of the American coast. We also discovered that the balance of evidence about the nature of the deep sea portion of the route was in favor of the truth of the statements made by the Atlantic Telegraph directors. For instance, on July 6th, 1866, we published the following information:—"In the absence of direct evidence, and with the possession of very scanty data, it seems reasonable to suppose that currents act in places upon the cable bed, but probably

with a very moderate velocity. Should such be the case there is a chance of the prolonged duration of the cable in working order. In the neighborhood of the Banks of Newfoundland it seems likely to receive the roughest usage .... The greatest difficulties in the way of the submergence of the line are found on the further half of the cable track, and although the chances are in favor of the paying out being performed successfully, they are against the maintenance of telegraphic communication for any considerable period."

In another article, published the following week, we made the following statement:—"The great fact rendering it doubtful whether the cable can be maintained is that off the coast of Newfoundland, it will be subject to attacks from icebergs. These icebergs are brought down in dozens from the polar regions by the cold southward current, and they ground on the fishing banks at the exact point where the cable crosses their track." Again, on the 27th July, 1866, we said:—"The coasts of Newfoundland and Labrador not only have these inhospitable icebergs sailing round their shores, but are themselves, as a rule, rugged and precipitous, and formed of granitic and primitive rocks. The entrance to the harbor of St. John's is of this character. Where the ground is thus uneven above water, it is not unreasonable to assume that it is the same below, especially as the few soundings taken north of the Banks of Newfoundland show great irregularities in the depths. More data about this portion of the ocean bed should be obtained before an opinion can be formed as to the permanency of a cable laid thereon." Such being the facts of the case, of course common sense taught that a thick length of shore-end cable ought to be laid over this dangerous part of the track; so in the same article we said:—"Possibly future years will prove that the most lasting form of Atlantic cable is one with a very thick shore-end all the way from Heart's Content to a point to the north-east of the coast of Newfoundland." Had this simple suggestion been acted upon, and, when the cable was afterwards first fished up for repairs at this spot, had a thick length been laid all the way to the shore, the shareholders would have had a very small outlay, and saved untold thousands of pounds.

Not satisfied with giving the foregoing advice once, we did so again on August 3d, 1866, as follows:—"If the main body of the cable prove durable, the length of it in the shallow water north-east of Newfoundland is too slight, as the soundings there denote rough, uneven, and rocky ground. The ridges of the neighboring coast are of granitic and primitive rocks, running north-east and south-west; so that if the same formation prevails below water, as may reasonably be inferred, the cable crosses the rock nearly at right angles. Five miles of thick shore-end are laid off Heart's Content, but to the mouth of Trinity Bay, and across the rough ground north of the Banks of Newfoundland, the thin 1-in. cable is used. In the uncertainty whether the line could be laid or not, of course it would have been very injudicious to have made several hundred miles of thick cable for this bad portion of the route, although past experience demonstrates that this portion of the line must be thickened, when Atlantic telegraphy is proved, as we think it will be, to be a safe and reasonable subject for the investment of capital." Lastly, a warning was printed by us on July 20th, 1866, pointing out the necessity of so laying the two cables that when grappling for the one the other might not be accidentally hooked and broken.

All these things have come to pass. While the deep sea portions of the cables have all along, so far as the directors let the public know, been in good condition, the lengths close off Newfoundland have been cracking and breaking with chronometrical regularity, from the very first, and year by year cable-repairing ships have been at work on the spot, with all the regularity of the cod-fishers. And they will probably have to persevere in this interesting work until they lay down a length of good thick cable at this place. Why has the Anglo-American Telegraph Company not done this before? Is it from unwise stinginess? Is it from want of intelligent and competent engineers to advise and assist the directors? There seems to be a sad deficiency of brains somewhere.

The last breakage of the 1866 cable took

place about three months ago off the Newfoundland coast. While fishing for the faulty cable last November it is supposed that the second one was accidentally hooked and broken, so now both are silent. A vessel is now out fishing for them, but whether there is a supply of good thick cable on board we do not know; if not, the Atlantic cable fishing season will come on again next year with its usual certainty. This cable-repairing work is a difficult task, requiring the greatest engineering and naval skill; for it is obviously no easy task to keep a ship stationary over one spot, amid shifting winds and currents, while a splice is being made. Captain Blacklock has had more experience in this work than any living man; we do not know whether it is he who will repair or attempt to repair the present faults, but we trust that those attempts will be successful, and that on the way home he and the crew will not be troubled by ghosts, who, according to published statements, were very busy on board the ship on his way home from his last expedition.

Notwithstanding the shortcomings pointed out in this article, the Atlantic Telegraph directors and workers have done useful and noble work; they have not only laid good cables, but proved that in deep water they are durable. Probably as iron is quickly eaten away by seawater, they might be durable had they no iron sheathing; if so, the deep-sea cables of the future will be vastly cheaper than those of the present day.

COAL AND IRON.*

By J. S. NEWBERRY, M. D., LL. D.

From "The American Chemist."

Coal is entitled to be considered as the mainspring of our civilization. By the power developed in its combustion all the wheels of industry are kept in motion; commerce is carried with rapidity and certainty over all portions of the earth's surface, the useful metals are brought from the deep caves in which they have hidden themselves, and are purified and wrought to serve the purposes of man. By coal, night is in one sense converted into day, winter into summer, and the life of man, measured by its fruits, greatly prolonged. Wealth, with all the comforts, the luxuries, and the triumphs it brings, is its gift. Though black, sooty, and often repulsive in its aspects, it is the embodiment of a power more potent than that attributed to the Genii in Oriental tales. Its possession is, therefore, the highest material boon that can be craved by a community or nation. Coal is also not without its poetry. It has been formed under the stimulus of the sunshine of long past ages, and the light and power it holds are nothing else than such sunshine stored in this black casket, to wait the coming and serve the purposes of man. In the process of formation it composed the tissues of those strange trees that lifted their scaled trunks and waved their feathery foliage over the marshy shores of the carboniferous continent, where not only no man was, but gigantic salamanders and mail-clad fishes were the monarchs of the animated world.

On this picture, however, we have no time to dwell; our present purpose is to consider coal in its utilitarian aspect, and to show what it is, and for what it can be used.

That the assertions I have made in regard to the economic value of coal are not exaggerations, will be apparent by a glance at the present material condition of the civilized world.

Of all the nations of Europe, England is the most powerful, because she is the richest. Though occupying a group of islands insignificant in area, she has spread her power over the entire globe, and it is her boast that the sun never sets on her possessions. It is well known to the political economist that the source of England's wealth has been her manufacturing industry; and the mainspring of her industry has been her stores of coal. In this respect she enjoys a great preeminence over all the nations of Europe. The United Kingdoms have a coal area that has been reckoned at 10,000 square

* Extracted from the Report of Progress of the Geological Survey of Ohio in 1869.

miles, while, in round numbers, Belgium has 500, France 2,000, Spain 4,000, and the other nations of Europe still less. The annual coal production of Great Britain is now more than 100,000,000 tons, and a very short calculation will suffice to show what an important contribution this makes to her national wealth. The power developed in the combustion of a pound of coal, is reckoned by engineers as equal to 1,500,000 ft. lbs. The power exerted by a man of ordinary strength, during a day of labor, is about the same ; so that a pound of coal may be regarded as equivalent to a day's labor of a man. Hence, 300 lbs. will represent the labor of a man for a year. It has been estimated that 20,000,000 tons of the annual coal product of Great Britain is devoted to the development of motive power, and that this is equivalent to the labor of 133,000,000 of men. These men, in this calculation, are considered as exerting merely "brute force;" but since they may all be regarded as producers only, and not consumers—the profit on the balance of her coal product fully covering all expenses—we are safe in estimating the contribution made to the wealth of Great Britain, by her annual coal product, as equal to that of 133,000,000 of skilled operatives laboring for her enrichment.

Such being the value to a nation or community of this combustible, let us see how our nation and our State have shared in Nature's gifts.

The area of the coal-field of carboniferous age, lying within the limits of the United States, has been estimated at 150,000 sq. miles. The productive coal area of Ohio is not less than 10,000 sq. miles, or quite equal to that possessed by Great Britain, and far in excess of that of any other European nation.

I have said that the annual coal production of Great Britain is over 100,000,000 tons—a rate of expenditure of capital which is seriously alarming British economists. In Ohio the annual coal production is now about 3,000,000 tons. So it will be seen that we not only have an almost inexhaustible source of wealth in our coal fields, but that as yet we have scarcely begun to draw from this treasury. Hence, I was justified in saying, as I did, that this promised to be by far the most important source of our power and material progress; and one of the most important duties pressing upon our legislators, and on us as geologists, is, by all means in our power, to promote the rapid and intelligent development of all the industries that are to spring from this source.

In order that we may more clearly apprehend the nature and capabilities of the material which has such potency, and with which we are so richly endowed, I will briefly describe some of the varieties which it exhibits, and the uses to which they are adapted.

Coal is now considered by all chemists and geologists of any standing, as of organic origin, and it may be easily demonstrated that it has been derived from the decomposition of vegetable tissue. As we find it in the earth, it forms one of a series of carbonaceous minerals which represent but different stages in a progressive change from vegetable tissue as found in the living plant. In peat and lignite, we witness the first step in the formation of coal. *Peat* is bituminized vegetation, generally mosses and other herbaceous plants, which, under favorable circumstances, accumulates in marshes, hence called peat bogs. *Lignite* is the product of a similar change effected in woody tissue ; and because it retains, to a greater or less degree, the form and structure of wood, it has received the name it bears. Peat is the product of the present period, and lignites are found in deposits of recent geological age. In the older formations, these carbonaceous accumulations, still further changed, are *bituminous coal.* Where special and local causes have operated to carry the change still farther, as where the beds of coal have been involved in the upheaval of mountains, and heat has acted upon it, it is converted into *anthracite.* Where this metamorphosis has been carried still further, the result is *graphite,* or black lead.

Most of the mineral fuels employed by the civilized nations of the world belong to the class of bituminous coals ; but in our own country, up to the present time, by far the largest quantity of coal produced and consumed has been anthracite, because our beds of coal which lie nearest the seaboard, and have been longest worked, are of this character. These are, however, of the same age with our Ohio coal beds, and the peculiar phase which

the coals of Eastern Pennsylvania exhibit, is due to the fact that a portion of the great Alleghany coal field was involved in the upheaval of the Alleghany mountains, and the coal, in common with the associated rocks, was greatly metamorphosed; its gaseous matter being nearly all driven off by the great heat which attended the elevation of the mountains.

The changes which vegetable tissue has suffered in passing through the various stages I have enumerated, are not only physical but chemical. They have been carefully studied by several eminent chemists, and have been so fully explained, that they may be comprehended by any intelligent person. The *rationale* of this process may be seen at a glance by reference to the following formulæ:

Wood.		Loss.	Peat.
Carbon	49.1	− 21.50	= 27.6
Hydrogen	6.3	− 3.50	= 2.8
Oxygen	44.6	− 29.10	= 15.5

Wood.		Loss.	Lignite.
Carbon	49.1	− 18.65	= 30.45
Hydrogen	6.3	− 3.25	= 3.05
Oxygen	44.6	− 24.40	= 20.20

Lignite.		Loss.	Bituminous Coal.
Carbon	30.45	− 12.35	= 18.10
Hydrogen	3.05	− 1.85	= 1.20
Oxygen	20.20	− 18.13	= 2.07

Bituminous Coal.		Loss.	Anthracite.
Carbon	18.10	− 3.57	= 14.53
Hydrogen	1.20	− 0.93	= 0.27
Oxygen	2.07	− 1.32	= 0.65

Anthracite.		Loss.	Graphite.
Carbon	14.53	− 1.42	= 13.11
Hydrogen	0.27	− 0.14	= 0.13
Oxygen	0.65	− 0.65	= 0.0

From this table it will be seen that the change from wood tissue to peat or lignite, and from these to bituminous, thence to anthracite coal and plumbago, consists in the evolution of a portion of the carbon, hydrogen, and oxygen, leaving a constantly increasing percentage of carbon behind, until ultimately the resulting mineral consists of a portion of the original carbon of the plant with all its earthy matter. That portion of the original substance which is lost in the progressive change, escapes in the form of some hydrocarbon, as water, carburetted hydrogen, carbonic acid, petroleum, etc. The escape of these volatile compounds we see in the gases bubbling up from marshes where vegetable matter is undergoing decomposition; in the gases generated in our coal mines, and, in my judgment, in our oil springs, which always flow from strata charged with bituminous matter. By the application of heat, and with proper management, we can manufacture any of these mineral fuels from vegetable fibre at will. This has been done repeatedly, and although we cannot accurately reproduce the conditions under which these changes are effected in nature's laboratory, we can so closely imitate them as to demonstrate their character.

We find also that, under peculiar circumstances, nature has departed from her usual routine, and has locally effected all the changes I have enumerated, in a short space of time; as at Santa Fe, New Mexico, where a trap dyke has cut through cretaceous strata in which are beds of soft and nearly valueless lignite, and where over a large area this outflow of melted rock has converted this lignite into a compact and valuable anthracite. So at Los Bronces, in Sonora, triassic coals are converted into anthracite by an eruption of porphyritic rock. On Queen Charlotte's Island, south of Alaska, is a tertiary (?) lignite changed by a similar cause into the most beautiful and brilliant anthracite I have ever seen.

All the coals of Ohio belong to the group known as bituminous coals; but these exhibit very considerable diversity in their chemical and physical characters, and the different varieties are adapted to very different uses.

Following an economic classification, our coals may be described as, first, *dry, open-burning or furnace coals;* second, *cementing or coking coals;* third, *cannel coals.*

The first of these includes those that do not coke and adhere in the furnace, and are such as may be used in the raw state for the manufacture of iron.

The second group, to a greater or less degree, melt and agglutinate by heat, forming what blacksmiths term a "hollow fire." This property causes them to choke up the furnace and arrest the equal diffusion of the blast through the charge. Hence they cannot be used in the raw state for the manufacture of iron, but must be "coked." This process of coking consists in burning off the bituminous or gaseous portion; which leaves them in the condition of anthracite, except that, as this change is effected without pressure, the resulting material is cellular and

spongy. Coals of this character, when free from sulphur—their great contaminating impurity—are used for the manufacture of gas; the volatile portion, driven off in the retorts, serving the purpose of illumination, while that which remains is coke, and may be used as fuel.

The cannel coals have usually a more distinctly stratified structure, are more compact and homogeneous in texture, and contains a larger percentage of volatile matter than the others; also the gas they furnish has higher illuminating power. Hence they would be used, to the exclusion of all others, for the manufacture of gas, only that the coke which they furnish is of inferior quality. They are, therefore, for the most part, employed as household fuels—for which they are specially adapted—and, in small portions, for enriching the gas produced from coking varieties.

The marked differences exhibited by the kinds of coal I have enumerated, are doubtless due, principally, to the circumstances of their formation. The furnace coals have generally a distinctly laminated structure, and are composed of bituminous layers separated by thin partitions of a material allied to cannel, which does not coke. Hence the bitumen in them is held in cells, and cannot flow together, and give the mass a pasty, coherent character.

The cementing coals have few such partitions, but show, upon fracture, broad brilliant surfaces of pitch-like bitumen. Both these varieties are supposed to have been formed in marshes, where they were saturated, but not constantly covered by water. The cannel coals were deposited in lagoons of open water in the coal marshes, where the finely macerated vegetable tissue accumulated as carbonaceous mud. Hence they have a large percentage of hydrogen, and their gas has high illuminating power. Hence, also, the remains of shells, fishes, amphibians and crustacea, all aquatic animals, so generally found in them.

While it is true that coal is, as we have called it, the mainspring of modern civilization, it is also true that much of its value depends upon its association with iron. In the few words I have devoted to our coal deposits, I have done nothing like justice to their richness and value; and while Ohio cannot boast of an equal endowment in iron, it may at least be said that she has fully her share of this element of wealth. In most countries, certain varieties of iron ore are found associated with coal, black-band, clay-iron-stone, etc., and in these ores Ohio is richer than any of those States that share with her our great Alleghany coal-basin. Again, our coal-field is so situated, and the coal it furnishes is of such quality, that a large part of the richer crystalline ores found in other States must inevitably be brought to our territory to be smelted and manufactured.

In order that the conditions under which the production of iron is now, and is hereafter to be, carried on in Ohio, may be better understood, I will devote a few words to a description of the different varieties of iron ore found in our country, and their relation to the fuel with which they are to be smelted.

The richest of all the ores of iron is the "Magnetic oxide," which contains, when pure, 72.4 per cent. metallic iron, and 27.6 oxygen. It consists of the protoxide and sesquioxide combined, and may be recognized by its black powder and its magnetic property. This variety of ore is found in great abundance in the crystalline rocks of the Alleghany belt, in the Adirondacks, and in Canada. It is the ore brought to us under the name of Champlain ore, from the fact of its occurrence on the shores of Lake Champlain, and is that mined so extensively in Southern New York, New Jersey, and further south along the same line. From its abundance in the localities I have cited, and its proximity to the anthracite coal of Pennsylvania, this ore has formed the basis of a very large manufacture in the Eastern States, and has furnished more of the iron produced in this country than any other single variety.

As found in Canada, and along the Alleghanies, the magnetic ores are extremely prone to contain certain impurities, which injuriously affect the metal produced from them. These are principally phosphorus in phosphate of lime, and sulphur in the form of sulphide, or iron pyrites. Of these, the phosphorus renders the iron "cold short," or brittle when cold; and the sulphur "red short," or tender at a red heat. Many of these ores contain also a large percentage of titanium, by which they are rendered refractory,

and the iron made brittle. These defects in the Eastern magnetic ores almost preclude their use for the finer qualities of iron and steel, and yet they are destined to form an important element in the manufacture of iron in Ohio. Iron-making is, in one aspect, much like oil-painting, for, as the painter gets his finest effects by skilfully blending many tints, so the iron-maker can only obtain his best results by using in the furnace several varieties of ore. The iron ores of Eastern New York and Canada may, by the cheapness of return freights, be delivered within our territory at a price so low that they will continue to be used, as they now are, in considerable quantities, by our iron-smelters. Some of the Canadian ores can be furnished on the Lake shore at a very low figure, but these ores are so largely contaminated by sulphur or titanium that they are, at present, but little used. When, however, we shall have introduced the Swedish roasting furnace, which will remove, at little cost, 3 and even 4 per cent. of sulphur, we may expect these ores to be much more largely imported than they now are.

The ore next in point of richness to the magnetic, is that called "Specular iron," which consists, when pure, entirely of peroxide. This is a crystalline ore, generally having a metallic appearance, and takes its name from the speculum-like reflections from its polished surfaces. When free from foreign matter, this ore contains 70 per cent. of iron, and 30 of oxygen. Most of the Lake Superior ores are of this character, as are also those of the Iron Mountains of Missouri. To us the Lake Superior ores are of immense importance, as will be seen from the fact that at least two-thirds of all the ore mined in the Marquette district are brought to our State; and this ore constitutes the main dependence of all that great group of furnaces which have been constructed in the northern part of the State within the last 20 years. The product of the Lake Superior iron mines for 1868, was 507,813 tons; for 1869, 643,283 tons, and of this, at least $\frac{1}{3}$ is supposed to have been smelted with Ohio coal. The Lake Superior ores are almost entirely free from phosphorus, sulphur, arsenic, and titanium, the ingredients which so injuriously affect iron ores elsewhere; and the magnetic ores of Michigan, of which the supply is now known to be large, are the purest of which I have any knowledge. From these facts, it is evident that the Lake Superior iron ores are peculiarly adapted to the production of all the finer grades of iron and steel; and indeed it is the opinion of our most accomplished metallurgists that the manufacture of steel in future years, so far as this country is concerned, will be based almost exclusively upon these ores.

As I have before stated, the coals of the Alleghany coal field are superior to those of the West; and it is certain that nowhere can an abundant supply of mineral fuel suitable for smelting the Lake Superior ores, be so cheaply obtained as in Ohio. Some portion of these ores are now, and will continue to be, smelted with charcoal on the upper peninsula of Michigan, but the supply of this fuel is so limited that it will play but an insignificant part in the iron manufacture of the future.

I have already referred to the iron ores of Missouri. These have become famous through the descriptions published of the magnificent deposits of Iron Mountain, Pilot Knob, Sheppard Mountain, etc. These are specular ores of excellent quality, and are of importance to us, since they are now used to a considerable extent in the southern part of the State, and still larger quantities are destined to be brought to our coals which outcrop on the banks of the Ohio.

The ores which I have enumerated, constitute, with our native ores, the main source of supply to our furnaces. I should add, however, to this list one other variety—that which is known as the "fossil ore," a stratified red hematite, found in the Clinton group, and which forms a belt of outcrop extending, with more or less intermission, from Dodge county, Wisconsin, across a portion of Canada, entering New York at Sodus Bay, passing through Oneida county, where it has received the name of the "Clinton ore," thence running down, through Central Pennsylvania, Virginia, and East Tennessee, into Georgia and Alabama. In this latter region it is known as the "Dyestone ore," from the fact that it has been employed by the inhabitants for imparting a reddish brown tint to cloth. This Clinton ore is an anhydrous peroxide,

containing from 40 to 50 per cent. of metallic iron, and generally a notable percentage of phosphorus. Its use in Ohio has depended upon this latter quality, from the fact that it imparts a "cold-shortness" to iron made from it, and is supposed to correct the red-shortness of sulphurous iron.

DESCRIPTION OF VIADUCTS ACROSS THE ESTUARIES ON THE LINE OF THE CAMBRIAN RAILWAY.

By MR. HENRY CONYBEARE, M. Inst. C. E.

From "The Artizan."

The coast line which this section of the Cambrian Railway followed for nearly 86 miles was indented by numerous estuaries, which were crossed by viaducts having an aggregate waterway of upwards of 5,000 ft.; most of these estuaries were very shallow, and the line traversed them on timber staging; in all cases, however, the viaducts across the low-water channels were permanent constructions, with wrought-iron superstructures resting on cast-iron piers. The viaduct over the tidal water of the Dovey had an opening span of 35 ft., on the principle first used by Mr. Brunlees, M. Inst. C.E., in the viaducts in Morecambe Bay. The channel was not more than 3 ft. deep at low water of spring tides, and as it was important to complete the bridge as rapidly and as cheaply as possible, the author employed ordinary piled foundations, fixing a cast-iron splice at the top of each timber pile, and driving it with it, so that the whole length of the timber should be sunk in the bed of the channel. So placed, timber piles would last as long as cast-iron; they afforded a much cheaper foundation, and one more rapidly executed than screw piling. A similar expedient was adopted in constructing the fenders for the opening span of the Barmouth viaduct. The construction of the viaduct over the estuary of the Mawddach, at Barmouth, presented some difficulties, owing to the peculiar character of the foundation, and to the extraordinary velocity of the current at certain times of the tide. This viaduct had a water-way of 2,600 ft. The estuary extended about 10 miles inland, and at the point where the railway crossed it, was constricted to less than one-half its normal width, by the projection from Cader Idris of a craggy promontory, called Figle Fawr. The deeper water (54 ft. at ordinary spring tides) was close to the northern shore, and the northern bank, which was of basalt, shelved down almost precipitously into deep water; beyond this the bed of the channel was of sand, constantly shifting and varying in depth from 2 ft. to 8 ft. Below the sand was a bed of compact gravel from 6 ft. to 8 ft. deep; and below this again a peat bog, to a depth not passed through in the preliminary borings. The piers next the northern bank were placed on shelving rock, and were necessarily cast-iron cylinders. But the unknown depth of the peat under the other portions of the channel, rendered the employment of cylinders inapplicable for the remaining piers, and screw piles were consequently used. The bed of gravel over the peat was all that could be depended upon to carry the bridge, and as this was too thin to be loaded heavily, the spans were reduced to 40 ft.; and in order to equalize the load on the piles, and to distribute it over a larger area, the six piles of each pier were arranged in two equilateral triangular groups of three each, the upper lengths of each group forming a tripod. The diameter of the screw discs was 3 ft., and the load about $2\frac{1}{2}$ tons on each square foot of their surface, which was about one-half their sustaining power; after the surface of the channel had been covered with stones, this bearing area was supplemented by discs of 4 ft. and 4 ft. 6 in. in diameter, which were bolted on to the piles and rested on the stone-work. To avoid weakening the crust of gravel on which the stability of the bridge depended, the screw discs of the piles were placed 8 ft. up the piles. The inconvenience inseparable from this mode of construction, when applied in such an exposed situation, was attributed to the fact, that the piles of which each pier was composed—though sufficiently strong collectively when the

pier was complete, and all its constituent parts firmly braced together to withstand any stress of weather—had little individual strength when standing singly, or remaining unbraced, while the pier was in process of erection. The works, therefore, were somewhat delayed by piles being broken, and the staging for fixing them was swept away during heavy gales while the piers were in progress; but there was no instance of the slightest accident occurring to a pier after the bracing was once completed.

Considerable difficulty was experienced in sinking the cylindrical piers, owing to the velocity of the current, and the works had on one occasion to be suspended for some months. The opening span was 47 ft. between the points of support, which was contracted to 36 ft. by the fenders. The description of drawbridge to be employed in closing this opening was determined by the specialties of the foundation of the pier from which it was projected, which were on hard rock, shelving abruptly in a direction transverse to the axis of the bridge. Hence a swing bridge was out of the question, and there only remained the telescope or sliding drawbridge. Of these there were two varieties, the under drawbridge and the over drawbridge. The former was devised and first employed by Mr. Brunlees, and was that adopted by the author for the opening span of the Dovey viaduct. The over drawbridge was less generally known, but one had been erected some years previously at Rhyl, and had worked satisfactorily. Irrespective of its general mechanical advantages, of working more easily, and of being lowered into position, instead of being lifted up into it and supported in it, the over drawbridge was much better adapted to the requirements of the Barmouth site, in respect to foundation, than the under drawbridge, for the latter required at least a second row of piles for the support of its sliding drawbridge, and as this had to be withdrawn between and within the supports of the contignous bay, its width was either restricted, which in this case would have interfered with the footway alongside the railway bridge, or the intervals of the piles it slid between were unduly increased.

ADDRESS OF MR. HENRY BESSEMER BEFORE THE IRON AND STEEL INSTITUTE.

From "The Engineer."

On entering upon my duties as President of the Iron and Steel Institute, I cannot but feel deeply sensible of the honor you have conferred on me by your election ; and, at the same time, I fully recognize my inability to do justice to the occasion, and must therefore entirely throw myself on your indulgence.

Among the various manufacturing industries of the world, there is, perhaps, not one possessing so absorbing an interest as the manufacture of iron, whether viewed as a source of national wealth, of social advancement, or in its purely scientific character. The history of its discovery extends far back into the night of time and is lost amid the imperfect records of incipient civilization. As time rolled on, the production of this valuable metal appears to have kept pace, and gone hand in hand with the advancement of the arts, both of peace and war, down to the period at which we have now arrived.

On the 23d of June, 1869, it was the good fortune of the members of this Institute to listen to a most interesting account of the rise and progress of the iron manufactures, delivered by the noble president in his inaugural address ; an account not only touching on its ancient history, but bringing it down by successive steps to the present period. This address, as you will well remember, was also accompanied by statistics, both of the home and foreign iron trade, so complete, so interesting, and so exhaustive, as to leave no standing ground for me in the same direction. There are, however, some points of interest which have cropped up since that period which I propose to bring briefly under your notice ; after which I must ask you to follow me a little way off the beaten track prescribed by

custom in addresses like the present. I say briefly, because I should not like to anticipate the more interesting details of the latest improvements in the iron and steel manufacture which we may hope to have brought before us by the authors of the various papers to be submitted to your notice.

Among the many important problems still waiting for solution in the malleable iron manufacture, is the process of mechanical puddling, a process which presents so many practical difficulties to its successful accomplishment as to have hitherto heavily taxed the inventive talent and perseverance of many able men, who, though baffled for the time, have returned again to the charge, full of energy and determination. Most of the members of the Institute had an opportunity, during their visit to Wales last summer, of seeing the highly ingenious apparatus designed by Mr. Menelaus, of Dowlais, for this purpose. That such appliances should not have accomplished all that was desired of them is in itself a standing proof of the difficult nature of the task he had taken in hand. The want of success that has hitherto awaited these efforts is the more to be regretted, because the work of the puddler is one so laborious, and so exhausting to his physical and vital powers, as to render it desirable, for every reason of humanity, that hand puddling should be superseded by mechanical force. The advances made in this direction at the works of M. de Wendell, and at other works in France, are most interesting. Through the kindness of Mr. Menelaus, the committee formed to report on this process will have an opportunity of witnessing it in operation at the Dowlais Works, as soon as the apparatus can be got into working order.

While these laudable efforts are still progressing in the mechanical department of the iron manufacture, the chemical side of the question has not been lost sight of. It will be remembered by many present that, in the early part of this century, the various qualities of the iron of different districts were considered as the simple and inevitable result of some radical difference in the iron itself, such as we meet with in different kinds of wood, and in other organic substances. The science of chemistry has, however, long dispelled these erroneous notions, and shown that the simple elementary substance, iron, is precisely the same all over the world, and that the great variety in the quality and properties of this metal, as found in commerce, depended entirely on the quantity and number of other substances retained in combination with it, and, hence, that it might be possible to produce from every kind of iron ore a pure and perfect metal. The great encouragement which the enunciation of these facts at once gave to the manufacturer, led him to study the best means of purifying and separating from iron the deleterious matters found in combination with it. These efforts have had the happiest results, although we are still very far from the ideal standard of perfection which contemplates the production of an equally pure iron from all the known ores of that metal; this much, however, has been accomplished; the rule of thumb has given way before the proofs of chemistry, and the iron manufacturer of to-day no longer believes in some occult difference in the nature of the iron he treats, but his well-ordered laboratory furnishes him daily with the quantity and quality of the deleterious matters which his raw material contains, and which, as is now well known, consist chiefly of sulphur, phosphorus, and silicon. The latter substance is, for the most part, removed in the refinery and puddling furnace, but the two former still make a determined stand, and are never, in practice, so completely eliminated as to render the metal as pure as that obtained from ores where these substances are entirely absent. It is, however, no small point gained, that we know the numbers and nature of the enemies we have to struggle with. Such knowledge is said to be half the battle, but the other half is still, I fear, the most stubborn. Among the workers in this direction is Mr. Henderson, of the United States, who proposes to remove these deleterious substances by the employment of fluoric acid, in combination with oxygen; I have, however, not yet received any information as to the results obtained by the means proposed.

A second competitor in this interesting field of research is Mr. Sherman, also an American gentleman, who has been carrying on a number of experiments at the works of Sir John Brown, at Sheffield, and at other places. The invention is, I

understand it, consists in the use of iodine, or its compounds, brought into contact with the metal in the puddling furnace, or in the Bessemer converter. This problem, on purely scientific or chemical grounds, is one of considerable interest, nor is it less so in a commercial point of view ; but under the latter aspect it resolves itself chiefly into a question of how far the low-priced quality of pig iron can be made to equal the results obtained from the purer brands, and how near the cost of the process will bring up the inferior iron to the cost of the purer qualities at present in the market. On these points I have no information that would warrant me in hazarding an opinion either one way or the other. Further experiments are, however, I understand, about to be made so as to decide these important questions ; in the meantime we cannot but wish every success to the invention, which, if attained, would be of great commercial value.

Without having at all studied the question, it would at first sight appear, that instead of employing so expensive a substance as iodine in its manufactured state, that the half-vitrified ashes of sea-weed, which are rich in iodine, might be applied direct to the iron in its first process of manufacture in the blast furnace—or, by simply charging on with the rest of the material the requisite quantity of sea-weed in its raw state, or only previously dried. The carbonate of soda, chloride of potassium, and other salts, derivable from the sea-weed would, in any case, form an excellent flux, and lessen the quantity of lime required to produce a liquid cinder. It would also appear that the ashes of sea-weed, in the form of powder, could most readily be carried by the blast through the tuyeres into the Bessemer converter or at any stage of the converting process. I have found, in my early experiments, that blowing crude American pot ashes into the metal produces a very liquid cinder, but the tuyeres are more rapidly worn than when air alone is used.

Among the most important improvements lately effected in the manufacture of steel is the development, by Sir Joseph Whitworth, of the system of casting under hydraulic pressure. The casting of large masses of steel free from air bubbles has long been a source of difficulty, owing chiefly to the fact that at the extremely high temperature of molten steel a certain quantity of oxygen is absorbed and retained by the metal so long as this high temperature is kept up, but which it cannot keep in combination when the metal is cooled down to the point at which it commences to solidify ; hence, when the fluid metal is received in a cold mould, large volumes of gas are given off, some of which becomes entangled in the solidifying mass and is there retained, forming numerous cells or honeycombs. A similar result is met with in finery iron, when it is "overblown ;" carbonic oxide gas is liberated in abundance during the solidification of the plate metal, and gives rise to the peculiar cellular structure so well known. Another defect inherent in steel castings owes its origin to the crystalline structure assumed by the metal in the act of solidification. So long as the metal retains undisturbed the original crystals formed by casting, the mass is only feebly coherent, its tensile strength is less than half to which it rises when hammered or rolled. It will bend only a few degrees from the straight line without fracture, while its power of elongation is also extremely limited ; but if considerable pressure be applied while the steel is passing from the fluid to the solid state, the crystals, which would otherwise become almost independent structures, are united or welded together so perfectly at this high temperature, and in their almost plastic state, as to develop the most perfect cohesion of all parts of the mass, probably more perfect than any subsequent operation of hammering could effect. In a patent which I obtained in 1856 I described a method of casting steel under hydraulic pressure in iron moulds—a cold wrought iron plunger being forced into the semi-fluid steel at one end of the mould, through the agency of the hydraulic pressure applied to its opposite end. About the same period I had observed that in those cases where fluids gave off gaseous matters under ordinary atmospheric pressure, that they were prevented from doing so by increasing the pressure on their surfaces. A familiar example of this action is seen the instant we release the gaseous pressure by the removal of the cork from a bottle of champagne, and it occurred to me that if I subjected the fluid steel to additional

atmospheric pressure that the boiling of the metal in the mould would be prevented. Thus arose the first idea of casting under the pressure of air or gases pumped into a closed chamber of great strength, in which the mould and casting were enclosed ; but, owing to numerous engagements, these inventions were left in abeyance until attention was again called to the subject, a few years since, by Sir Joseph Whitworth, who, finding great difficulty in making steel castings free from air bubbles, and of sufficient cohesive strength for the manufacture of his guns and projectiles, hit upon the idea of subjecting the metal, while still fluid, to the action of a hydraulic plunger forced into the mould. His experiments, in connection with this system of casting, have been most successful. Indeed, I can bear witness to the extreme soundness of several large cylindrical masses, turned and bored, which were shown to me at his works, in neither of which the most minute flaw or bubble hole was visible. It was also stated that these simple castings under pressure were as strong, or even stronger than bars of hammered steel. In justice to Sir Joseph Whitworth, I feel bound to say that I have no doubt whatever but that he was wholly unaware of the existence of my previous invention at the time he brought forward his system of casting under hydraulic pressure, by which the material now known as "Whitworth metal" is produced. Certain it is that we owe to him the development and first practical application of this system of casting steel under a pressure transmitted direct to the fluid, or semi-fluid metal, by a plunger actuated by hydraulic force.

It is difficult to estimate the importance of any process by which a malleable metal, stronger than forged iron, might be readily cast at once into the desired form ; but it is just this question of form which still presents the difficulty. It will be readily understood that any plain parallel figure like an elongated shot, or a solid cylinder or ingot, may be compressed by a plunger at one end, and a tolerably uniform effect be produced throughout the mass of metal ; but it is far different with more complex forms. For instance, let us apply the same force to one end of a loam mould in which a double-throw locomotive crank is to be cast. In this case we should have two breaks in the continuity of the column pressed upon ; and even if it were possible to prevent those parts of the mould between the throws from being crushed in by the enormous pressure transmitted to the end of the crank, we should infallibly fail from another cause. The plunger would, doubtless, transmit the pressure throughout the whole mass so long as the metal remained fluid ; but this is just the period at which pressure is of little or no use as a substitute for forging ; it is when solidification and a reduction of bulk is taking place, by cooling, that the force is most needed, to prevent the formation of cavities in the central parts of the mass, and to cause that cohesion of the crystals which, in other cases, is effected by the after process of hammering. It will also be obvious that the ram would be wholly incapable of transmitting force throughout the contorted limbs of a crank axle while in the act of solidification. Hence, in this, and in hundreds of other required forms, the plunger system of transmitting pressure would prove an entire failure. There are also other insuperable difficulties in the way of this system of applying pressure to the general run of castings required in steel ; the mould for each article would have to be made of enormous strength, and be only very thinly coated on the inside with clay or loam, to prevent the crushing of these materials and the consequent distortion of the casting ; while the iron mould, having only a thin coating of yielding material, would oppose the natural contraction of the mass, which would tear itself to pieces. It, however, appears that all these difficulties may be at once overcome by simply using an ordinary mould box, and moulding the article in the common way ; a very strong hooped vessel being provided in which the moulds may be placed. The opening by which the metal is run into this vessel may then be closed by a screw plug ; an artificial atmosphere of considerable pressure may be gradually generated in the vessel by the combustion of a mixture of anthracite coal and nitrate of soda ground to fine powder, and producing an incombustible gas having any desired amount of pressure, and acting in all directions on the casting, but with no more strain on the mould than it would be subjected to under ordinary atmospheric

pressure. If by this, or any other means that may be suggested, we could obtain steel or malleable iron castings free from air bubbles and of great cohesive strength, an immense point would be gained. Those who have seen the beautiful castings in steel produced in Germany, by the Bochum Steel Company, and also those of not less merit produced by Messrs. Vicars & Co., of Sheffield, will fully appreciate the importance of giving to such castings the perfect malleability and cohesive strength of steel forgings.

Among the various improvements that have within the last few years been introduced in the manufacture of iron, few are of such magnitude and importance as the production of armor plates; a manufacture called into existence by the advances made in modern artillery. The rapidity with which manufacturers have responded to the call thus made on their skill and enterprise affords an excellent example illustrative of the way in which the engineering talent of this country seems capable of keeping pace with the ever increasing wants both of the arts of peace and war. The production of malleable iron, of the excellent quality of which these plates are made, also affords another proof of the rapid progress made in this department of our great staple manufacture.

In the early part of these remarks I proposed, with your permission, to touch on one or two subjects which, it appears to me, are matters of great importance not only to the members of the Iron and Steel Institute, but to the whole engineering profession, as well as to the public in general; and when I reflect on the thoroughly practical character of the many eminent manufacturers and engineers whom I have now the honor to address, the conviction forces itself upon me most strongly that such an organization as ours is one eminently calculated to solve many of the important practical questions, both in connection with the manufacture of iron and steel, and their employment for constructive purposes, which individuals, unaided and alone, might well shrink from grappling with. It is from the members of the Iron and Steel Institute that the world looks for a practical definition of the terms iron and steel. It is true that from a chemical point of view the line of demarcation which separates these substances is as little marked as the rainbow's hues, which melt imperceptibly into each other, leaving no part at which it may be said, here one ceases and there the other begins. Thus it is with iron and steel, which passes by almost imperceptible gradations from grey iron, through every stage of mottled and white, to hard steel, and from it to steel in its mildest form, which passes into malleable iron almost unmarked. Although admitting the truth of this view of the subject, when considered chemically, the practical man recognizes in the metal iron a substance which, in its more or less pure or alloyed state, and under its physical condition of cast or wrought iron, possesses properties so different and so anomalous, that its classification becomes both easy and natural; hence three primary divisions have everywhere been recognized, viz., cast iron, wrought iron, and steel; and allowing a certain latitude in each class, there seems no reason to dispute the propriety of such a definition. With regard to the two former, cast iron and wrought iron, their manufacture has been pursued so long in every civilized country that their nature and physical characters are well known and universally recognized; but, with reference to steel, this can scarcely be said.

In the latter part of the last century the ingenious clockmaker, Huntsman, found that steel made by the cementation of iron bars was rarely perfect enough in its structure to yield a clock spring of equal strength throughout. Unable to obtain a sufficiently reliable material, he hit upon the happy idea that the fusion of bar steel, if practicable, would furnish a far more reliable material, perfectly homogeneous in structure, and free from the numerous flaws which the accidental envelopment of wood ashes on the Swedish bar so frequently caused. Fortunately for mankind this bright idea was brought to the test of practical experiment; and, after numerous failures of every kind, Huntsman was at last enabled to construct furnaces that would furnish the necessary high temperature, and crucibles that were not destroyed at a single heat; he thus at last succeeded, by laborious efforts, in producing cast steel—the most valuable and perfect condition in which the metal iron is known. This valuable process was unprotected by

patent, and was kept a profound secret by Huntsman for many years. The way in which it at last became known is among the historical events of the past, that are better buried in oblivion.

At this period there was but little prospect of the extension of the use of cast steel to other than very exceptional purposes. Being made in crucibles, containing only from 5 lbs. to 7 lbs., its cost was very high, while difficulty of fusion at that time prevented any but extremely hard or highly carbonized steel from being made. The manufacturers of Sheffield have, however, gradually overcome these difficulties, and in the year 1851 the production of cast steel in Great Britain had risen to 1,000 tons per week; and at that time a plain square bar of 500 lbs. in weight could probably have been purchased at as low a price as £40 per ton! The great extension of the cast-steel manufacture within the last few years, its reduced cost of production, together with the facility now possessed of making it of a mild or tough quality, has brought it into competition with wrought iron for several most important uses in the arts. It is this fact which opens up the important field of inquiry to which I desire especially to direct your attention. So recent has been the application of mild cast steel to engineering structures, that the civil engineer finds himself at a loss to estimate its value as a constructive material and its applicability to the work he may have in hand. If he desires to use wrought iron, he has a thousand examples before him. He has printed tables and formulæ almost in every book he turns over, and in all this he is confirmed by numerous examples, and by his own practice and observation; but if he desires to employ steel for any new structure, be it the roof of some large building, a span of unusual length across a river, where intermediate piers are almost impracticable, or in any other case, in which he hopes by economy of weight he may obtain that in steel which he cannot hope to acomplish with a weaker material, where, under such circumstances, is he to look for the desired information? Where are the numerous tables he is wont to employ? Where the formulæ deduced from practice to aid his calculation? Where the example from which he can draw his own conclusions? It is to fill up this void, and to supply such information on the authority of the first practical men in this country, that I propose to establish proofs so well authenticated and so irrefragable as to form a sure basis for after calculation, and afford means of estimating the strength of structures, and to supply tables on which implicit reliance can be placed.

The great point, I take it, will be to make such tests comparative with iron in all cases, and under circumstances equally well adapted to show the comparative value of each material for structural purposes. This is the more necessary, because I believe that many of the tables and formulæ at present in use were made at a time when wrought iron had not arrived at so perfect a state of manufacture as that to which it has now attained. It would be, therefore, necessary to repeat every test in the wrought iron and steel of the present period in order to ascertain with precision their relative power of resistance under identical conditions, or under such special conditions as may be more favorable to either material.

Should it be thought desirable that the Iron and Steel Institute should investigate this subject, I would propose that a series of preliminary experiments should be made, showing the resistance of the different materials both to tensile and compressive force, as well as to violent concussions and long continuous strains, all of which facts could be furnished by the powerful machinery erected for this and similar purposes by Mr. David Kirkaldy, whose high position would be a sufficient guarantee of the correctness and perfect impartiality of any such report. I speak of these as preliminary tests only, because I think the members of this Institute will agree with me that it is not the simple breaking or twisting of a single bar, free at all parts except in one particular direction, that is wanted, but it is the more complex strains that we have to encounter in practice that it is desirable to ascertain and to record. Thus it would be necessary to make several beams and girders of such form and construction as will fairly represent the use to which iron and steel are applied in practice. It is in order to construct these test girders of proper proportions that I propose to make the first or preliminary experiments on the materials of which they are

constructed, and I would further propose that any errors arising from the imperfect apportioning of strength in the different parts of these girders should be corrected by reconstructing them after their weak places have been shown by a first trial, and thus arrive at a structure, as near as may be, equally strong at all points, and showing the exact amount of material necessary to withstand the tension and compression of the several parts of the structure. I will not trouble you just now with the details of the simple mode by which I propose to test these beams and girders; but I have little doubt but that they would be most satisfactorily carried out by Mr. Kirkaldy, so as to complete the whole series of tests in the most reliable form. Before quitting this subject I wish to draw your attention, briefly, to the special modes of construction to which I have before alluded, and which become necessary, because wrought iron and steel differ so much in the conditions of their manufacture as to render forms and sizes in one material easy and inexpensive, which would be almost impossible, or at least too costly, in the other. For example, in a large plate girder the upper and lower webs are usually composed of numerous pieces of plate iron riveted together in several thicknesses, entailing the labor of punching numerous holes, the employment of many rivets, and much labor of fitting together, and, in the end, accompanied by a considerable reduction in strength as compared with a solid slab of the same metal. It will at once be obvious that in the manufacture of cast steel great facility is offered in making large masses, as compared with the production of such masses of wrought iron; thus, where steel is employed for the top or bottom web of a large girder, it is evident that the simplest way would be to roll a single slab of the desired dimensions, thus avoiding the labor of cutting the plates to size, and punching and riveting them, and thus also avoiding the great loss of strength consequent on the loss of section at the rivet holes. It would therefore appear that on any comparison of the two materials for a given structure, the facility which steel affords of supplying large masses must be taken into account. Nor is this all, for steel may be made with equal facility either hard or soft, and in the upper web of a girder steel specially adapted to bear a high compressive strain may be most advantageously used. A single glance at Hodgkinson's cast-iron girders shows at once how small a top web is necessary in a material so difficult of compression as cast iron, while its weakness under a tensile strain is in like manner exhibited by the massive proportions of the lower web. Although the difference in the two qualities of steel will not allow so great a difference in the proportion of a steel girder as we see in the cast iron one, it would, I believe, be of sufficient magnitude to considerably alter both the weight and cost of the structure. This harder material might be used in all cases where compressive strain alone was used, and, in order not to complicate the manufacture by numerous qualities of steel, one special quality might be fixed on for this purpose, and be distinguished from the usual make as *steel for compression.*

It would be no less interesting to ascertain how far the properties of wrought iron and steel combined in one structure could be advantageously employed with the view of affording with a given weight, or at a given cost, the greaetst amount of stability in structures of this kind. I have hitherto spoken only of beams or girders as affording examples of the nature of the tests which I deem desirable; but it will be obvious that these researches should be so modified and conducted as to afford correct data to the ship-builder as well as to the engineer. Indeed, I believe that steel has already been somewhat largely employed, in combination, for shipbuilding, by the late Chief Constructor of the Navy, with the intention of developing a greater amount of strength with a given weight of materials.

I believe it will be found that the rate of expansion of iron and steel within the limits of atmospheric temperatures will oppose no practical obstacles to their combined use. The advantages to the manufacturers which would result from an exhaustive series of trials on a practical scale, such as I propose, would be further enhanced by the readiness with which the Board of Trade and other public bodies would thereby be induced to approve structures of steel, or steel combined with iron, the weight and dimensions of which are subject to their approval.

Before closing these remarks there is another subject which I desire to bring before your notice, because it is one on the merits and importance of which you are so well able to decide.

The great development of the mechanical arts within the last century has rendered it extremely desirable that certain uniform standards of size, or measure, should be set up, by means of which a uniformity of practice has, in many cases, resulted. Thus we owe to Sir Joseph Whitworth a series of standard gauges which have been universally adopted in engineering establishments, to the great advantage of the manufacturer and the user of the machinery in which these accurate and definite sizes of parts have been introduced. The same may be said of the Whitworth screw threads so generally employed in our mechanical workshops. But perhaps the most marked application of the employment of standard screw threads is found in the manufacture of welded iron gas pipes, from which we derive an amount of advantages which, owing to our familiarity with it is rarely appreciated to its full extent. So obviously advantageous is this system, that we happily see its principle extending from day to day, even to an entire mechanical structure, as in gun-making, where every part is made to a standard pattern, so that the possession of a few duplicate parts will enable a broken or otherwise useless rifle to be perfectly restored in a few minutes, at a cost immeasurably below that which would have been required to make a single part to order. And it must be borne in mind that this system of standard sizes not only affords great advantages to the general public, but it lessens the cost of production, by admitting of the employment of special tools and appliances for the production of these numerous pieces, which could not be employed in the chaotic state reigning in our manufactories before these principles were applied. In the early days of our railway system, the great Stephenson and his compeers had to feel their way gently in the new career they were pursuing; their engines were mere toys compared with those we now employ, and the loads they drew were small in proportion. It was therefore only necessary that they should employ a rail suitable to the traffic of the lines as then worked; but as the railway system began to develop itself, and new lines were opened, the necessity for heavier engines and greater traffic became apparent to the engineers by whom they were designed. Nor was the mere addition of size the only point studied; different modes of laying down the rail were proposed and were canvassed with great interest. Stone blocks gave way to cross wood sleepers, and these again had their rivals in longitudinal sleepers, and with them came the bridge rail and the Vignoles rail, and the double-headed rail now commonly in use. Nothing could be more natural than the way in which the profession thus glided imperceptibly into the adoption of rails of almost every imaginable variety of form and size, nor can any one be blamed for a result almost inevitable under the circumstances.

But it is now evident that there is no need in practice for this infinite variety of size and form; we know pretty accurately what is the general average traffic on a line and the weight of our engines. The work which a rail has to perform is so perfectly simple, and so clearly defined, that there cannot at the present day be any difficulty in establishing a standard rail suitable for all purposes.

Thus, suppose we take the double-headed and the Vignoles rail as representing the two classes of rails suitable for longitudinal cross sleepers, and if we make a heavy, medium, and light one of each of these types of rail, we should have a choice of six sizes that would supply all the reasonable demands of our present railway system. Taking these three standard sizes of iron rails, of each class, I would then make three other standards of steel rails, in which the table or wearing surface was identical in each case with the iron standard, but so reduced in weight per yard as to reduce its powers to resist a blow or to sustain a weight precisely equal to the iron standard, so that in all cases the iron *a b c* rails and the steel *a b c* should possess the same powers of resistance to a heavy load, or a sudden concussion. We should thus diminish the great apparent difference in price between the iron and steel rail, for it must be remembered, *that the price per mile and not the price per ton*, is the real test of the *cost of rails*. The adoption of a standard rail would afford great facilities to the manufacturer by diminishing

his stock of *rolls* and allowing him to manufacture in slack times, and to supply any sudden demands from stock. It would lessen the cost of production and afford the general advantages to the consumer and producer which have hitherto resulted in all cases from the adoption of universal or standard measures. It is difficult to imagine the state of utter confusion that would have reigned throughout our whole railway system had the gauge differed on every line to the same extent as the rails. The one instance afforded by the broad gauge is sufficient to convince us of the immense disadvantages that would have resulted from such an error, and I doubt not but should we happily arrive at a universal *a b c* standard for rails, we should in the future look back with dismay on our present chaotic state.

I therefore feel a conviction that the time has arrived when a conference with our leading railway engineers would result in the adoption of an iron and steel *a b c* standard for rails, to the great advantage of all concerned. There would, of course, be no difficulty in supplying, if required, *outside sizes* at a *higher quotation.*

In the course of these remarks, I have ventured to bring under your notice two proposals, which appear to me deserving of the attention of the Institute, and which are intimately connected with the interests of many of its members. I have done so with much diffidence, because I cannot but be aware that I am addressing many gentlemen who are far more able than myself to form a correct opinion on the subjects I have been discussing; I must, therefore, beg that you will clearly understand that I have no wish to put forward these propositions with any force as coming from the chair; indeed, I do not know that such subjects should have been broached at all in an address like the present. I feel, also, that I owe you some apology for dwelling at such length on the subject of steel, but I have felt it almost impossible to avoid doing so.

THE CONTRACTION OF THE EARTH.

By B. PEIRCE.

From "Nature."

The phenomena, which were ably presented by the distinguished geologist, Mr. Lesley, to the National Academy of Sciences, and which seem to demonstrate that the outer shell of the earth has sensibly shrunk, in some directions at least, since its original formation, naturally invite the attention of physicists to the possible causes of such a result. The most obvious cause of the shrinking of the earth is its cooling. But to shrink 2 per cent. linearly, which is the amount deduced by Mr. Lesley from the observed geological phenomena, involves a probable cooling of the whole earth of not less than 2,000 deg. Centigrade, which would require that its original temperature should be higher than would be consistent with the solidity of these shrunk strata.

Another source of change of form, which would produce shrinkages in different directions in different parts of the earth, is to be found in the diminution of oblateness arising from the diminished velocity of rotation upon the axis. Such diminution of the velocity of rotation has several years ago been shown by Mr. Ferrel, to be caused by the action of the moon in producing the tides; this is, therefore, a true cause, and it is only necessary to examine how great its amount can be, under any circumstances. This is all which is proposed in the present investigation, and the application to facts is reserved for geologists.

It is sufficient, for the present object, to regard the earth as homogeneous. Under this condition, Laplace has shown that the time of the earth's rotation could not be less than about $\frac{1}{10}$ of a day, which corresponds to a ratio of the axis of the equator to that of the pole, equal to 2.7197, and an equatorial circumference 94 per cent. greater than the present one. Such is, then, the amount of shrinking which might have taken place, if any cause could be assigned capable of producing so great a reduction of the earth's velocity. The whole surface of the earth would have been about 130 per cent. larger than at present.

But the only cause at present known which would produce a sensible reduction of the earth's velocity is the lunar action upon the tides. But in this mutual action between the moon and the earth, the common rotation area of the earth and moon must remain unchanged. The question then arises, How great a reduction of the rotation area of the earth would have passed into that of the moon? In this inquiry it may be assumed that the moon revolves in a circular orbit in the plane of the earth's equator.

Now, the moon's rotation area is 3.716 times the earth's. But if, in the origin, it had revolved just in contact with this earth, its rotation area would not have been less than 0.480 times the earth's, so that it could not have absorbed a rotation area from the earth greater than 3.236 times the earth's present rotation area, and therefore the earth's rotation area could never have exceeded 4.236 times that which it has at present. But, with the maximum velocity of rotation given by Laplace, the earth's rotation area would have been 37½ times greater than at present. It can never, therefore, have been reduced to so great an extent by the moon's action on the tides. But since, when the oblateness is small, the rotation area is nearly proportional to the velocity, and the excess of the square of the equatorial above that of the polar axis is nearly proportional to the square of the velocity, this excess may have been originally nearly 18 times as great as at present, or about 15½ per cent. of the square of the polar axis. This would correspond to a figure of the earth in which the equatorial radius would have been about 2½ per cent. greater than at present; so that it is sufficient to account for the observed phenomenon.

This peculiar form of shrinkage would produce the highest mountains at the equator, and the tendency of the mountain ranges would then be to assume the direction of the meridian. But nearer the poles the mountains would be less elevated, and would rather tend towards the direction of the parallels of latitude.

It is, next, expedient to consider the mechanical question of the loss of living force in the case of the moon's action upon the waters of the earth, and its effect upon their different motions. In this connection there are problems worthy of the attention of geometers; such as the relative motions of bodies rotating above the same vertical axis, towards which they are drawn by weights, and acting upon each other through the friction on the axis. For one of the bodies a rotating wheel may be substituted. There is also the case of two planets revolving about a primary, and acting upon each other through some form of friction.

In this way it will be seen that the planet or satellite once formed is constantly removed from the primary, and that planets tend to approach each other. It is interesting to consider whether this may not be one of the actual problems of nature.

GUNPOWDER FOR HEAVY GUNS.

From "Engineering."

The irregularities observable in the results of the proof of the 35-ton gun at Woolwich have reopened a question which was thought to have been definitely settled by the careful experiments of the Committee on Explosives. This question is the exact form and size of grain that shall be given to powder for use in our heavy guns. In an article which appeared in our journal last week, we discussed at some length the various points connected with this subject. It will, therefore, be unnecessary here to repeat them, or to do more than mention that the Committee on Explosives, under the presidency of Colonel Younghusband, R.A., have resumed their labors, with the view of solving this question. In pursuance of their purpose, they carried out some experiments at Shoeburyness on Wednesday and Thursday last week, which had an important bearing on the question at issue. The practice was intended to determine the quantity of pebble powder that ought to be used as a service charge for the new 11-in. Woolwich muzzle-loading rifled gun, as well as for guns of a somewhat smaller calibre. The new 11-in.

gun is about the same weight as the 12-in. 600-pounder, its weight being 24 tons 19 cwt. 2 qrs. The projectiles fired on the recent occasions were Palliser shells, weighing, empty, 535 lbs., and common shells brought up to the same weight with lead. The piece was mounted on a 23-ton gun wrought-iron sliding carriage, of 56½ cwt., and wrought-iron platform, fitted with hydraulic buffer, containing 12 gals. of oil, and a piston with 3 holes of $\frac{9}{10}$ in. in diameter.

The details of the practice are given in the following Table :

Table Showing the Practice with the 11-*in. Gun.*

Round.	Weight of powder charge.	Character of powder.	Projectile.	Velocity in feet per second.	Recoil.	Pressure in tons.
No.	lbs.				ft. in.	
1	70	R. L. G.....	Common shell	1102	4 1	31.9
2	70	"	Palliser "	1206	4 3½	27.6*
3	70	"	" "	1212	4 8	....
4	75	Pebble	Common "	1267	4 8	....
5	75	"	Palliser "	1234	4 8	19.7
6	75	"	" "	1234	4 6	....
7	80	"	Common "	1275	4 8	....
8	80	"	Palliser "	1217	4 7	21.7
9	80	"	" "	1276	4 9	....
10	85	"	Common "	1309	4 11	....
11	85	"	Palliser "	1301	4 10	29.6
12	85	"	" "	1308	4 11	....
13	90	"	Common "	1313	5 0	....
14	90	"	Palliser "	1308	5 0	35.0
15	90	"	" "	1338	5 1	....
16	70	R. L. G.....	" "	1197	4 6	34.5

The velocities having been taken at a distance of 75 yards from the gun, 10 ft. must be added in each case to approximate the results to muzzle velocities. The pressures recorded were taken by Captain Noble's crushers placed in a copper cap at—with the exception of No. 2—the rear end of the bore of the gun. Where the pressures are not recorded they have not yet been ascertained, the crushers having been placed at the rear of the projectiles, which have to be recovered from the sands. In round No. 2 the crusher was placed at the rear of the projectile which was afterwards recovered. The R.L.G. presented unmistakable signs of very violent action, having in round No. 1 completely crumpled up the cap which it carried out of the gun 34 yards to the front. The velocity of the projectile was exceedingly low, but this may have been owing to the fact that this was the first round fired from the gun since its proof, and there may have been influences tending to diminish the velocity. The last round of the series, fired after the gun had got into working order, and when it would be free from any such influences, offers a direct comparison with the first round. In this case the violent action of the R.L.G. powder was again apparent, the edges of the crusher cap being distorted and bent over, the crusher was disconnected from the cap and deposited in the bore of the gun a few inches from the muzzle.

To arrive at the value of the results of the experiments with the 11-in. gun, we must first refer to the behavior of the two kinds of powder in the 12-in. 600-pounder gun. From known results in this case we find 67 lbs. of the R L.G. powder giving a muzzle velocity of 1,168 ft., and a pressure of 22 tons in the chamber, and 85 lbs. of pebble powder, giving a muzzle velocity of 1300 ft. per second, with a chamber pressure of 17 tons to the inch. In the practice with the 11-in. gun, it will be seen that the same quantity of pebble powder—85 lbs.—with a projectile 65 lbs. lighter than that used in the 12-in. gun, gave 29.6 tons pressure. So far it has been made clear that the increased length of chamber has materially increased the longitudinal pressure of the explosive gases. A comparison of the results of the R.L.G. rounds in our table with those fired with pebble powder

*Crusher placed at rear of projectile and recovered.

shows in favor of the latter, 75 lbs. of which gave only 19.7 tons pressure, as against from 31.9 to 34.5 tons with 70 lbs. of the former. Again, the 34.5 tons pressure from 70 lbs. of R.L.G. powder is only about balanced by the pressure from 90 lbs. of pebble powder, which is 35 tons, giving an excess of charge of nearly $\frac{1}{3}$ in the case of the pebble powder.

The next series of experiments was made with a 6.3 in. Palliser converted (68 pounder) gun. This was the experimental test for utilizing the heavy smooth-bore guns and carriages now in position in forts in India. The present weapon, as a smooth-bore, was an 8-in. gun, but it has been lined with a wrought-iron tube, and rifled to a 6.3 bore, and is at present the only gun of its kind. The gun was fired with L.G. and pebble powder, the pressures being taken by crushers placed in copper caps at the end of the bore. The practice is shown in the following Table:

Table Showing the Practice with the 6.3-in Gun.

Round.	Weight of powder charge.	Character of powder.	Projectile and Weight.	Velocity in feet per second.	Recoil.	Pressure in tons.
No.	lbs.				ft. in.	
1	12	L.G.....	Common Shell, 68 lbs....	1412	4 5	20.8
2	12	" ..	" " " ...	1466	4 5	25.7
3	18	Pebble...	" " " ...	1527	7 1	8.9
4	18	" ...	Palliser shell 90 lbs.	1377	8 3	10.9
5	18	" ...	" " "	1352	Taut up to breeching and slight rebound.	10.8
6	17	" ...	" " "	1347		10.9
7	17	" ...	" " "	1338		10.8
8	19	" ...	" " "	1362		9.4
9	19	" ...	" " "	1387		10 0
10	22	" ...	" " "	1477	Violent recoil...	18.3

The velocities were obtained at 50 yards.

The general conclusions derivable from the foregoing Table, as well as from the results of some previous experiments made by the committee, are that the service L.G. powder gives uniform results in this converted gun, the previous experiments to which we have referred showing that 15 lbs. of pebble powder, with a 90 lbs. Palliser shell, gives a mean velocity to the projectile of 1,290 ft. per second, with a pressure on the gun of 7.8 tons. On the other hand, 15 lbs. of L.G. powder gives 1,264 ft. per second only, with a pressure of 17.5 tons. An equal charge of pebble powder thus gives 26 ft. more velocity to the heavy projectile, and reduces the pressure at the end of the bore by more than one-half. We may also observe that in the previous series of experiments to which we have referred, the detailed results of which are before us, 20 lbs. of pebble powder gives a 90 lbs. Palliser shell a mean muzzle velocity of 1,445 ft., with a mean pressure of 12.9 tons. It is therefore possible that by using pebble powder we shall increase the velocity of the projectile by 180 ft. per second, and yet reduce the pressure by $\frac{1}{3}$ as compared with the battering charge of L.G. powder, which was fixed at 15 lbs. L.G. with a 90 lbs. projectile when the gun was proved.

The further testing of this 6.3 in. gun for range and accuracy is being carried out, and upon the termination of the trials, if successful, it is probable that 100 of these guns will be ordered forthwith for the Indian Government. The results obtained as regards the pebble powder show it to be far superior to the powder in ordinary use for heavy guns, although we are inclined to think that a smaller kind of pellet powder—that of $\frac{5}{8}$ in. diameter, and $\frac{9}{16}$ in. deep, cylindrically shaped and with convex ends—would produce still better results. At any rate we presume the Committee on Explosives intend to give this powder, which they can obtain from Hounslow, a fair trial before they conclude their labors.

Gold of New Zealand.—The yield of gold for the year 1870, shows an increase of 20,000 oz. over the preceding two years.

A SINGLE-RAIL TRAMWAY.

From "The Artizan."

In thinly-peopled and mountainous countries, and especially in many parts of Turkey, the want of roads for internal communication is the great difficulty in the way of national progress. It is also a difficulty well-nigh insurmountable by the methods to which we are accustomed in the more favored parts of Europe, because there is no capital available for the purpose of making communications that would have to create their own traffic, and that would probably ruin the owners before they had done so. For example, about ten years ago, a road was made from Beyrouth to Damascus, and upon this there is not only not a single native wagon running, but the muleteers and camel drivers take the old break-neck track by choice, because it is shorter from point to point, and is free from the trifling toll which is charged on the highway. Moreover, in such countries the value of an ordinary road is much diminished by the inevitable steepness of the gradients, which render it necessary that a wagon could carry but a small load. A carriage road is now being constructed, at a vast expense, between Alexandretta and Aleppo; and seems likely to be as little traversed as that to Damascus. It is being carried through the pass of Beilan; and, in order to obtain even tolerable inclines, a distance which is only 70 miles by mule tract will be increased to more than 100 by the new road. Mule and camel drivers will certainly not use it, more especially as it is badly supplied with water; and as the steepest gradient will be 1 in $7\frac{3}{4}$, it is difficult to conceive that wheel traffic can ever become a source of profit. A railway on the European system would be simply impracticable. Water and fuel are scarce, skilled labor is expensive and would have to be imported, the country is very difficult, and the whole value of the transport to and fro is now about £62,000 a year. At £10,000 a mile the cost of constructing a railway would be a million sterling; and, when working expenses were paid, little would remain for the shareholders. Such a line may possibly be needed hereafter as a portion of a route to India, through Alexandretta and Aleppo, to the Euphrates, and thence to Bagdad, and, as it would pass through a fine grain country, it may eventually be in itself profitable. The present need, however, is to provide a means of traffic not much in excess of the actual or probable demand, and suited to the wants of a country in which railroads are impossible from their cost, in which roads are useless because the natives find that carriages do not pay, and in which there can be no canals, because water will not run up hill. In the face of these conditions Mr. J. L. Hadden, C.E., has devised a single-rail tramway for conveyances, of which he gives the following description:—

"Imagine a bicycle let into a longitudinal aperture in the centre of the bottom of a cart, and the cart nearly touching the ground, so that only about 6 in. of the wheels would be visible; next, a kind of balancing pole run through the sides of the cart at right angles to the single rail on which the bicycle is to run. The 2 ends of the pole are to project about 3 ft. on either side of the cart, and rest upon, and be harnessed to, the backs of 2 mules. The animals will thus be 1 at each side of the load, instead of being in front in the ordinary way. It would be impossible for the cart to turn over, because, in order to do so, it would have to force one mule to the ground and to lift the other into the air; and, moreover, as its floor would only be 6 in. above the rail, an overtip would be of no account. All the weight in the cart, if evenly distributed, would bear upon the rail, and the animals, having no load on their backs, would be able to exert considerable traction power."

Mr. Hadden thinks it an incidental advantage that with such a tramway the muleteers would be compelled to keep the appointed way, instead of leaving it, as they now do, by side tracks that enable them to avoid toll bars; but, at the same time, he proposes to give the wheels broad double flanges, so that in case of need the carts would run upon any good road. He states that responsible contractors are prepared to lay his single line, with 30 lbs. rails and De Bergne's pot sleepers, at a cost of £450 per mile, all sidings included.

Mr. Hadden does not consider that the utility of his invention will be limited by the precise conditions that first called for it. He not only suggests its employment for military purposes, but also for tramways in large cities; and he says that, where space is very valuable, a horse or mule on only one side of the cart would be sufficient. In towns, on bridges and other important places, the rail might for a short distance be dispensed with; and passenger vehicles should be fitted with small friction wheels on either side, so that, if a horse should fall down, the balance of the carriage would remain undisturbed.

TELEGRAPH COMMUNICATION WITH INDIA.

From "The Engineer."

In the face of existing political combinations, and the expectation which appears to be pretty generally entertained regarding the intentions of Russia with reference to Turkey, the subject of our existing means of telegraphic communication with India assumes a greater importance than has hitherto attached to it. At present there exist three routes by which messages may be sent, two of which, forming the principal routes of communication, meet at Bushire, and thence transmit their messages to India by the Persian Gulf cable between Bushire and Kurrachee, whilst the third route is *via* the Mediterranean and Red Sea, and thence by a deep-sea cable between Aden and Bombay. It was not until the year 1858 that any practical schemes were proposed for establishing telegraphic communication between England and India, although so far back as 1855, Mr. Lionel Gisborne applied to Messrs. Glass, Elliott & Co. for information to enable him to prepare estimates for the carrying out of a telegraphic line to the East. Shortly after this, concessions were obtained from the Sultan, which were made over to the Red Sea Telegraph Company, for laying a line between Alexandria and Aden. The capital was fixed at £800,000, upon which sum the English Government guaranteed interest at the rate of 4½ per cent. for 50 years. The construction of the cable was intrusted to Messrs. Newall & Co. The line was laid, and messages were actually transmitted by this route; but after a short period the signals failed, and all attempts to restore the communication for any length of time proved fruitless. This line has, however, recently been restored, and it is connected from Aden with Bombay by means of a deep-sea cable, and from Alexandria through the Mediterranean with Malta, and thence, *via* Gibraltar and Lisbon, with Falmouth. Direct communication by this line is also available through France and Italy to Malta. The whole line by this route, therefore, consists of an alternative land and submarine line to Malta, a submarine line thence to Alexandria, a land line across the Isthmus of Suez, and a submarine line from Suez to Bombay. It must be admitted that hitherto this line has not attracted so much of the Anglo-Indian traffic as its importance from a political point of view warranted its promoters in expecting it would receive. The other lines are known as the Russian route and the Turkish route, both joining at Bushire in the Persian Gulf, whence two submarine lines extend to Gwadur, and alternative land and submarine lines thence to Kurrachee.

The route *via* Russia consists of a double line from London to Teheran, passing through Circassia and Georgia, belonging to the Indo-European Telegraph Company; a line through Persia, belonging to the Persian Government, but worked by British officers, passing through Ispahan and Shiraz to Bushire, where it joins the Persian Gulf line. It will thus be seen that the communication between England and India by this route is entirely under the command of Russia, and might at any time be interrupted in the event of that nation desiring to interfere with it. Any one who may have watched the movements of Russia in the East, and her more recent intervention with reference to Cashmere, can hardly fail to detect the continuance at the present day of her ancient policy with regard to our Eastern possessions. The route *via* Turkey is approached by five lines from London to the Turkish frontier. Their direction is as

follows:—(1) From London to Turkey, *via* Holland and the Austro-Germanic Union; (2) from London to Turkey, *via* Belgium and the Austro-Germanic Union; (3) from London to Turkey, *via* France and the Austro-Germanic Union; (4) from London to Turkey, *via* France, Switzerland, Austria and Hungary; (5) from London to Turkey, *via* France and Italy.

Fom the Turkish frontier the lines converge to Constantinople, when a special line runs *via* Bagdad to Fao, and there joins the submarine line of the Indian Government through the Persian Gulf. These lines are not likely to be interfered with by any power desiring for its own political purposes to interrupt free communication between England and India, so far as the lines through Europe are concerned; but it is clear that by cutting the line at Constantinople the route through Turkey would be practically closed, and all the alternative lines through Europe be rendered useless. In the absence of united European interference it is clear that the power of closing this telegraph route to India is also in the hands of Russia, with power to exercise it at her will.

There remains, then, only the third, or Red Sea route, which could be relied upon in the event of any attempt on the part of Russia to seize our Indian possessions, or even to create a diversion in India with the view of weakening our powers of interference in European—possibly Turkish—affairs. Under these circumstances it may be asked—is it wise that we should be content with a single line of telegraph as our only sure means of communication with India in the event of certain not improbable contingencies, especially when an alternative line might be established with the greatest ease by the addition of a short submarine cable between Alexandria and Seleucia, at the north-east corner of the Mediterranean Sea, and thence by a short line to Aleppo, joining the existing route to Bagdad and the Persian Gulf? It is true that a land line exists from Alexandria to Cairo, and from the latter place along the eastern coast of the Mediterranean past Jerusalem, Tripoli, and Aleppo, to Diarbekir; but the objection to this is that it is not entirely in English hands, as any line between England and India should be throughout its whole length.

Now that the question of the Euphrates Valley route to India is again being revived—and its establishment has already been too long delayed—the proposed new telegraph would follow the line of the Euphrates river from Aleppo as far as Babylon, where it would join the existing line to Basra and the Persian Gulf, instead of following the valley of the Tigris, which is the course of the existing line from Constantinople. It is not probable that any danger of interruption of the Russian and Turkish lines will, so far as Russia is concerned, be allowed to be anticipated by England by reason of any premature action of hostility on her part; but, nevertheless, any precaution by England to secure her communications with India in the face of any contingencies, cannot but be deemed a wise policy, and any expenditure incurred for such a purpose would certainly not be deemed an act of extravagance, even if the necessity for it be not absolutely justified by future events.

* * * * * *

There are, it appears, already two parties in the field endeavoring to obtain concessions from the Turkish Government, viz., Mr. W. P. Andrew, Chairman of the Sind and Delhi Railway, for the construction of a line *via* the Euphrates; and Messrs. Waring Brothers, who are anxious for permission to survey for a line of railway along the valley of the Tigris, following, as will be seen, the route of the telegraphic lines between Turkey and Persia. The importance of maintaining the integrity of our telegraphic communications with India by this route cannot well be overestimated, and with the view of rendering it more perfect a second cable was laid down the Persian Gulf in October, 1869, between Jashk and Bushire, by Mr. Latimer Clark. The cable was manufactured in England in the summer of 1868, chiefly under the superintendence of Mr. F. C. Webb, and the laying of it was superintended by Mr. George Preece, under the direction of Mr. Clark himself. The total length of cable shipped from England was 535¼ miles, and the length paid out 504.39 knots, which was made up as follows:—

Shore end at Jashk	3.622
Shore end at Bushire	10.260
Main cable	490.508
Total	504.390

The distance measured along the course is 496.5 miles.

The first Persian Gulf cable, which is of gutta-percha, maintains its original resistance of about 400 megohms per knot, but the second cable, being of Hooper's india-rubber core, gives a resistance of 1,704 megohms per knot, the insulation, in both cases, being measured after one minute's electrification.

ON A VESSEL IN MOTION, AND WHAT BECOMES OF THE WATER SHE DISTURBS.

By HENRY RANSFORD, Esq., Associate.

From the "Journal of the Society of Arts."

In considering the subject, an important difference between solids and fluids must not be overlooked: it is this, in forcing a solid into another solid the particles are frequently compressed together, without altering the external form of the bodies, as driving a post into hard ground, or a nail into a block of wood; but, water being incompressible, a body forced through it, floating partly above and below the surface, or a solid let down into it, alters the form, and in either case that can only be done by raising the surface; and, unimportant as this proposition may seem at first sight, it is a principle that cannot be set aside; and, although witnessed by many every day, yet in regard to its real effect on the movement of ships it has not yet been duly considered. Another great difference between solids and fluids to be considered in the movement of vessels is, that the particles of the latter so readily communicate motion one to another without materially altering their position; thus it is a common saying with seamen, when speaking of a fast steamer, to say "her bow is so sharp, that she does not raise even a ripple before her," not considering that a great displacement and consequent movement of water to the surface somewhere has taken place, but which, being some distance ahead, or obscured by the motion of the waves, they have not perceived.

To observe the effects on water by a vessel in motion requires peculiar opportunities, that rarely occur to a sailor or persons interested in this difficult problem; it can only be seen perfectly by the side of a river, when a steamer is passing, and the surface of a glassy smoothness, and in the greatest perfection, morning or evening, when the sun is not very high above the horizon, and the tide does not cover all the shingle. If a person will then take his stand and watch a steamer approaching, he will see a wave advancing a little ahead of her, and spreading out in a curve that reaches the shore. Selecting a large pebble close to the water's edge, or driving in a small stick as a mark, he will see, as the wave approaches, the water rises and covers his mark. The wave having passed on, the water subsides, and then recedes quite as much below as it had risen above the previous level (like a stream running towards the steamer); then in a few seconds comes another wave, rising fully as high as the first one, followed by several smaller ones, which diminish in size, until the surface of the water again subsides to the same condition as before the passing of the steamer.

I was first struck by the receding of the water behind the first wave below its previous level, and was soon convinced that not merely a carrier wave had passed along the surface, but that the steamer had set in motion a stratum of water the whole distance between her bow and the advancing wave—that is, the particles of water communicated motion one to another from the bow, until they rose as a wave above the surface, which, on losing the thrust of the stratum as the boat advanced, commenced to spread or subside, but I could not at all account for the receding of the water after the passing of the wave. I at once commenced to observe closely the various kinds of craft passing up and down the river, and the effects produced when they were moving with the tide, against it, or in still water, and soon found the results were the same, but differing according to the state of the tide and the build and speed of the ves-

sels. All bluff bows similar to barges (when being towed) raised a wave very close immediately in front of them with very little spread, the effect of which on a vessel would be similar to a wheel of a cart sinking in soft ground. Ordinary bows sent the waves further ahead with an expanding curve, and the sharper the bow the wider the arc, thus increasing the distance from the wave to the bow, consequently lessening the resistance of the displaced water sent to the surface; and I observed the wave of displacement (as I term it) invariably travelled at the same rate as the vessel, irrespective of the depth of the water, quickly subsiding when a steamer stopped at a landing stage, and commencing as soon as the boat started again.

After referring to some experiments on the Erie Canal, he said:—These observations took a long time to note before feeling satisfied as to their correctness, and the invariable effect on the water. The inference that I at length drew from this accumulation of facts was, that all bows strike the water at a right angle from the plane of their curve; consequently what is considered an ordinary good bow, strikes the water with a downward as well as a side force, thus giving the particles or stratum of water, when first set in motion, a partially downward direction; then moving upwards in a curved line (the curve depending on the resistance received) until a wave is forced up on the surface, equal in bulk to the displacement, between the stem and the extreme beam of the vessel. A sharp bow striking the water more laterally than downwards, the wave of displacement does not rise to the surface so near the vessel as in the former case. The resistance not being so great from having less curve before it rises, it has a longer inclined plane (if I may so term it) to move on in its upward progress. It was evident that the following waves flowed on to fill up in some way the space left by the forward movement of the vessel; but it was a long time before I could account for the receding of the water on the shore, behind the wave of displacement. Close observation, on very calm mornings, at length showed me there was an evident depression of the surface of the water, commencing alongside the steamers, and extending towards the shore. Reasoning on this fact, I perceived it was caused by the water close to the vessel's side sinking down to occupy the space she was leaving. A screw steamer shows this far plainer than one with paddle-wheels. One fact, clearly proving the displaced water is first forced downwards by an ordinary bow before it rises, is this: a steamer, say between Hammersmith and Kew, goes slower directly she gets into shallow water. The men on board say "she drags;" the real truth is, the stratum set in motion by the bow strikes the bottom, and, instead of curving gradually upwards as in deep water, has considerable reaction against the bow, causing the vessel's head to rise and her stern to drop. Judging from these observations, it appears that what causes one ship to sail faster than another—other things being equal—is the shape of bow, which forces the water she displaces laterally, rather than downwards; for, action and reaction being alike, water forced downwards against water of greater resistance reacts against the bows, and consequently the more lateral the thrust, so much less will be the reaction; because the water is only forced against water of the same pressure, and the wave of displacement rises more easily to the surface. Now the displacement by the bow, and the sinking down of the water which fills up the space the vessel is leaving, must be simultaneous movements, and the particles of water in each case must communicate motion to those next to them, at the same velocity; it follows, that so far as the wave of displacement would extend on either side, and so fast as it would travel, just so far and so fast would also the particles of water be affected that are set in motion, to fill up the space the vessel is leaving; consequently, the receding on the shore is the action of the natural law of fluids filling up the space the vessel is leaving. It seems impossible that the space a vessel is leaving can be filled up in any other way than by the water in contact with the sides sinking down to occupy the space; the idea that the water comes up somehow from below, is surely opposed to the law of fluids. I ask what power rises or lifts it up? what water takes its place? I leave it to wiser heads to determine, but I believe it may be accepted as an axiom, that the limit to the speed of a steamboat, however powerful the engines, is the rate at which water

will flow in to fill up the space she leaves; and further, that the following must be recognized as laws in hydrostatics, viz., any ship or vessel floating in water can only move through the same by forcing to the surface a body of water of equal breadth and depth to its immersed midship section; and the bows of all ships in motion impel the water they displace at a right angle to the plane of their curve.

RAINFALL AND WATER SUPPLIES.

From "The Mechanics' Magazine.

That the water supply of towns has a very close connection with the average rainfall in the adjoining districts, is a fact too patent to require corroboration. The question may then be asked, is the rainfall year by year sufficient to afford a proper supply of water to the inhabitants of any given locality? That is just the point we purpose to consider in the present article. In other words, is the natural supply of water equal to the natural and artificial demand for it? It may be premised, as a tacit assent to the circumstance that the rainfall is supposed to yield the quantity required, that the first duty of an engineer who is called upon to design water-works for a town is to ascertain in a very careful and accurate manner the average rainfall of the neighborhood. Upon this he bases his calculations. It becomes therefore a very important detail to determine what the demand is likely to be, for not only will the supply be thereby regulated, but the cost of the reservoirs and other works be proportionately increased or diminished. The quantity of water necessary to meet the requirements of a town is usually stated at so many gallons per head per diem, and in many, in fact in all cases, there is very little attempt made to reduce this to a reasonable minimum; but, on the contrary, to raise it to as high a maximum as possible. There are very few water-works of any pretensions to magnitude which do not profess to give over 30 gallons per diem for each item of the population, and the actual quantity used is frequently very much in excess of this. It is unnecessary to mention that the waste of water in all large towns is notorious, and is one of those crying evils that ought to be stopped without any ceremony whatever. Next to air, water is the element most essential to life, and although it is a penal offence to wilfully allow it to run to waste, either by negligence or defective piping and cocks; yet from the want of adequate supervision, the enactment is a complete dead letter. As may be expected, engineers differ in their estimate of the quantity of water that is requisite for the supply of towns. It has been stated by Mr. Hawksley that from 16 to 17 gallons per head per diem would be an ample allowance, provided none were wasted. This quantity, which it must be borne in mind includes all that is required for trade purposes, appears at first sight a very low estimate. But this is only by comparison with the larger allowance, which is swelled by a liberal percentage expressly for waste. The proposition is apparently accepted, that there must be an unavoidable enormous loss of water, and that instead of it being practicable to check this and keep it within narrow limits, the only alternative is to allow for it. Instead of grappling with the evil and overcoming it, the easier but more reprehensible course is adopted of quietly sitting down under it, and making the best of it. Consequently all the necessary works of construction are on a much more extensive scale than that which would suffice for the purpose were that due regard to economy displayed which ought to characterize the treatment and use of so valuable a fluid. Another serious disadvantage arises from this excessive and costly liberality. In order to supply a large town the resources of the various catchment basins and drainage area are taxed to the utmost, and thus it frequently happens that while one town is lavishly provided with water, another in its neighborhood is very badly off for that element. The source that with proper care and the proper restrictions would furnish an adequate quantity for both towns is impounded solely for the benefit of the one.

As the quantity of water that may be

procurable for the supply of a town depends upon that which can be collected from the gathering ground, and as the latter in their turn depend upon the rainfall, the determination of the last mentioned is the real point at issue. This is of an exceedingly varying nature. The rainfall will vary with the locality, the climate, the altitude of the place where the observations are made, and also with its aspect with respect to the sun. As an example, the annual rainfall in the high gathering grounds of the Severn is estimated to be as much as seven times that in the lower situated lands of Essex. One would naturally conclude that it would be an easier matter to supply the towns with water in the former than in the latter district, but this is by no means an inevitable sequence. A very heavy annual rainfall does not necessarily imply a very large supply available for human consumption. The rain must be first caught and impounded before it can be utilized, and the quantity which can thus be collected is materially influenced by the geological nature of the gathering grounds. After rain has fallen it disposes of itself in three ways—part of it runs off, part is absorbed in the ground, and the rest is evaporated. This last part may be regarded under the same circumstances pretty nearly as a constant. The part that runs off is that most readily collected, although there is no doubt that a considerable percentage of that which is absorbed or percolated can be utilized by proper means. Rain, if not otherwise intercepted, will run off very rapidly into the nearest streams, if the inclination of the ground upon which it falls be very steep, or if it be of a rocky character. On the other hand, should it be of the nature of a table-land, a large quantity will be conveyed away by percolation and absorption. Some of this, especially if the land be insufficiently drained, as is generally the case, will find its way into springs and watercourses, and can be ultimately utilized. Again it is readily perceived that after a long continued rainfall, land that may be most prone to absorption will at length become so completely saturated or soaked that it will refuse to absorb any more or allow it to percolate through it. Under these circumstances the rain will either flow off it or remain on the surface and convert it into a marsh. If the land be flat and undrained the latter consequence is inevitable. There is another point to be borne in mind regarding the percolation and absorption of the rain water. A large quantity of it falling upon ground of this character may percolate through the overlying strata until it reaches one of an impermeable description. There it will remain impounded in the natural reservoir until it be "tapped" from above. The theory of well-sinking is founded upon the supposed existence at a certain depth of water-bearing strata of this nature, and the borings are carried down until the stratum be struck. Geology is the chief guide to works like these, but geology is nevertheless sometimes at fault. Many wells have been sunk hundreds of feet in depth, and after a large outlay of money the result has been very much below what was anticipated, and sometimes after sinking and boring until both money and patience were exhausted, the further prosecution of the undertaking had to be abandoned.

It is clear from what has been already stated that a very considerable discrepancy may and does exist between the amount of the rainfall and the quantity that can be be rendered available for consumption. If the whole of the rainfall could be caught and impounded, then the maximum utilization of it would be effected. Having shown that the original quantity of rain falling upon any given district suffers a considerable diminution before it is impounded, it may not be out of place to remark that the quality likewise is very much altered. Without going into extremes, water may be divided into two classes, hard and soft. The character or nature of these may remain constant, while their actual condition may vary. It is quite possible to have a pure hard or soft water and an impure one. Water may percolate or infiltrate through certain strata, which may have a purifying effect upon it. They may, in fact, act in some instances as a complete filter or strainer to the water, and discharge it in a very clear and pure condition. This property is possessed in an eminent degree by the sandstones, and schistose rocks are also favorable to the supply of good water. There are few gathering grounds which are throughout their whole area equally favorable to

the collection of water. If, for instance, a large portion of one be of an agricultural character the rain water flowing off is sure to be charged with manure to a greater or less extent. Similarly the existence of mineral deposits will affect the purity of the water. In estimating, therefore, the yield of gathering grounds all these circumstances must be taken fully into account, thus affording another proof that the whole of the rainfall cannot be included in the proposed supply for a town. There is still another important detail to be carefully attended to before the rainfall can be depended upon as a basis of calculation for a water supply. It is well known that the annual rainfall varies considerably, and, what is more to the point, there is nearly always a series of wet and a series of dry years consecutively.

A glance at a diagram of successive annual rainfalls, extending over a period of 20 or 30 years, will prove that it is a very rare circumstance for the maximum to be followed immediately by the minimum fall. There are, it is true, a good many jumps in the scale, but there is, nevertheless, a rough gradation from the highest to the lowest. Keeping in view, therefore, this annual variation, the question to be determined is, which particular rainfall or series of rainfalls is to be taken as the datum for basing the calculations upon. There is some diversity among engineers on this matter; many assume the driest year as the safest standard, but this is evincing, perhaps, an excess of caution. An average of the 3 driest years is a perfectly reliable datum. Intimately connected with this estimate is that of storage. It is well known that if a tenth part of the rainfall that finds its way first into rivers and streams and thence into the sea were impounded and stored, so that the superabundance of one year should counterbalance the deficiency of another, there would be no such thing as a drought. It would be impossible to build artificial reservoirs of sufficient magnitude for the purpose; but even if some means were adopted for retaining it in the ground in a water-bearing stratum, it would be ultimately of service, as it would serve to feed springs and wells. As it is, it is lost for ever. It is not like the water which is evaporated, which is recoverable as it is taken up by the clouds, and returned to the earth at a future period. But the sea restores nothing, and the conversion of the fresh into salt water precludes all possibility of its future utilization.

ON SOME NEW ENGLAND WATERS.

By S. DANA HAYES.

From "The American Chemist."

An unprecedented drought, of nearly 8 months, in this part of the country, has been the means of interesting many cities and towns, as well as individuals, in the subject of water-supply and its sources. It is customary, before introducing water, for the local authorities to employ engineers first, then obtain estimates and consult with citizens; the engineer naturally acts as a general adviser for his employers in such cases, and although I can bear witness that the majority of engineers recognize the great importance of previously analyzing waters intended for distribution in cities and towns, still there are instances where it has been entirely neglected. And the engineer is not always blamable, as, for instance, when he finds a water that tastes and smells badly, but which the analyst tells him does not contain any more grains of impurities in a gallon than one which he finds sensibly better, he does not understand why the smell and taste do not "weigh something." In this connection, the case of Cochituate water in 1854* is often cited, when it tasted and smelled of fish-oil (from crustacea in a peculiar condition), and was quite offensive; but the weight of extraneous impurity did not increase enough to turn the analyst's balance, and no oil could be seen in the water without a microscope.

But when the chemist is employed, and gives as much time to investigating the *kind* of organic matters present in waters submitted to him as is occupied in an-

*Proceedings American Academy of Arts and Sciences.

alyzing the mineral constituents, his results are of greater importance to the citizens as well as engineers, and often answer questions that can be decided in no other way.

I have analyzed many New England waters from a great variety of sources, and would like to place the ultimate results yielded by some of them on record in your valuable journal.

Table, showing the weight of impurities, in grains, in one United States Gallon, 231 cubic inches, of different waters.

No.	SOURCE.	Mineral malter.	Organic Matter.	Sotal Solids.
	MAINE:			
1	Pure spring near Auburn	0 85	0 13	1 98
2	Spring on Cape Elizabeth	7.40	2.21	9.60
3	Wells in Portland (average of four)	13.35	5.13	18.48
	NEW HAMPSHIRE:			
4	Merrimac River at Manchester (drainage)	2.96	2.60	5.50
5	" " at Lowell Mass	1.80	0.11	1.91
6	Massabesic Lake, near Manchester	1 16	1.66	2.82
7	Hotel well on Rye beach	6.08	2.43	8.51
	VERMONT:			
8	Mineral springs near St. Albans (average of seven)	15.24	1.25	16.49
9	" " at Gilford, (chalybeate)	25 27	1.65	26.92
10	" " at Brunswick	77.79	2.33	80.12
11	" " at Danby	7 19	0.91	8.10
	MASSACHUSETTS:			
12	Cochituate, Boston, February, 1871	2.37	0.83	3.20
13	Mystic, Charlestown, February, 1871	3.96	1.72	5.68
14	Jamaica Pond, Roxbury, 1867	2.41	1.36	3.77
15	Connecticut River at Holyoak (low water)	1.81	1.39	3.20
16	Saugus River, Lynn	3.12	2.40	5.52
17	Flax Pond, Lynn, (drainage)	2.24	1.84	4.08
18	Horn Pond Woburn	3.85	1 59	5.44
19	Locomotive supply, Taunton	4.37	2.03	6.40
20	Artesian well, Dedham	4.08	1.11	5.19
21	Wells in Woburn (average of four)	51.52	4.60	56.12
22	" Lynn (average of six)	19.27	4.23	23 50
23	Well on Cape Cod	10.01	2.41	12 42
24	Old Artesian well, Boston (reopened in 1871)	54.35	1 85	55.20
25	Brewery Spring, Boston	13.68	1.68	15.36
26	Dirty Brook, Boston(drainage)	9 44	12.48	21.92
27	Salt-water well	....	....	2082 0

No. 1 was supposed to be a "mineral water" by its owners.

Nos. 4 and 5 illustrate the natural purification of river-waters.

Nos. 12 and 13 were drawn from service-pipes in the respective cities.

No. 15 was perfectly clear, colorless, and apparently pure; but it contained vegetable extract that separated as a yellow semi-resinous body, when the water was brought in contact with chlorine, in the bleaching liquor of a cotton factory; there was no iron in this deposit.

No. 19 is not injurious for locomotive boilers; but No. 20 is one of the most corrosive waters that I have seen; it contains sulphur compounds, and had destroyed 2 boilers before being analyzed.

No. 21. Two of these waters contained, besides much salt, an uncommonly large proportion of nitrates, and corroded lead pipes very rapidly.

No. 22. One of these contained 5.96 grains of carbonate of zinc, from the service-pipes used in a dwelling-house.

No. 24 is an old omnibus stable well that had been covered for more than 20 years. Several thousand gallons were pumped ont before the sample was take for analysis.

No. 25 supplies water for one of the favorite ales made here, and is highly prized by experienced brewers.

THE daily product of petroleum in the Pennsylvania oil regions is 18,000 bbls.

THE STRAINS OF SHIPS AT SEA.

From "The Artizan."

A paper embodying an investigation of the strains which ships undergo at sea was read on February 9th, at the Royal Society, by Mr. E. J. Reed, C.B., late Chief Constructor of the Navy. The author, after pointing out that little or no practical progress had been made on this subject since the early part of the present century, proceeded to state that the introduction of steam navigation, and of iron and steel as shipbuilding materials, had rendered a thorough examination of it extremely necessary, and that he had consequently selected 4 ships, as types of the various descriptions of modern vessels —viz., Her Majesty's yacht Victoria and Albert, as a type of long, fine-lined, lightly-built ships, with great weight of engines and boilers in the middle; the Minotaur, as a type of long, fine-lined ships, with great weights distributed along their entire length; the Bellerophon, as a representative of short, stoutly built ships, with weights more concentrated; and the Audacious, as a model of ships with extremely concentrated weights. The smooth water strains of all these ships were illustrated by numerous diagrams embodying the results of various calculations, and the effects of placing such ships among waves were then no less fully investigated. The great bulk of the paper consisted of detailed calculations too long to insert, but some of the facts and figures deduced were very striking. It was shown, for example, that a ship like the Minotaur, floating among waves 400 ft. long and 25 ft. high from hollow to crest, which have a time of transit of about 8 ¾ sec., passed in half that time from a bending or breaking "moment" of 140,000 foot-tons tending to break her in two by the drooping of the ends to a reverse strain of 74,000 foot-tons, so that 15 times per minute a "wave of strain," as Mr. Reed designated it, having these enormous quantities for its positive and negative amounts, sweeps through the fabric of her hull. The Victoria and Albert yacht has to undergo, in like manner, strains which tend to break her downwards at the ends with a force of 16,400 foot-tons, and in less than 4 sec. encounters a strain tending to break her downwards at the middle, and let her engines and boilers fall through her, equal to nearly double this amount, or 31,000 foot-tons. It is remarkable that this change of strain in this lightly built hull is proportionately greater than that of either of the iron-clads. The Bellerophon's maximum strains in waves, similarly calculated, were 43,600 foot-tons and 48,800 foot-tons respectively. In illustrating the influence which rapid changes of strain exert upon structures, the author referred to the experiments of Sir W. Fairbairn, who has shown that the joints of an iron-riveted beam broke under the action of a rapidly alternating strain, although it was only ⅓ in amount of what the beam would sustain at rest. Mr. Reed stated that his investigations had shown many of the general principles laid down by former investigators, who had dealt with very different forms of ships, to be erroneous, and, in particular, opposed the very common notion that there is a compensating action between the strains of, and the wave actions exerted upon, very long fine-lined vessels. He further stated that while the weakness exhibited by many modern ships had induced him to enter upon these investigations, the result of them had been to convince him that calculations which had hitherto been neglected were becoming daily more and more necessary, especially as the length of steamships and the lightness of their construction in iron and steel were being very rapidly and simultaneously developed.

We hear that every steel rail manufactory in the country is now full with orders for the next 2 years, and that the price of the best Bessemer steel rail is some £12 per ton. The difficulty now appears to be not to pay for steel rails but to get them. This great demand for them arises from the marked economy in their use. Considerable savings are being made by our railway companies in the maintenance charges, due to steel rails. Thus experience has already supported theory as to the great advantage of steel rails.

STEAM ARTILLERY.

From "The Engineer."

Any proposition made by Mr. Bessemer, and published over his own signature in a public print, is certain to be read with attention by hundreds of men, who, like ourselves, admire his genius. In the present day, however, it is very well understood that no man is wise on all subjects, and we may add that this fact is especially true of Mr. Bessemer. We have perused with much care a long letter from his pen published in the "Times," which may be regarded as his latest contribution to mechanical science. It is to be regretted that the writer did not, before rushing into print, consult some competent engineer or mathematician as to the soundness of his views. Had he done so we fancy his own good sense would have stepped in to prevent him publishing a letter which is simply a tissue of absurdities. This is, no doubt, strong language, but we think that by the time our readers have heard what we have to say they will admit that no other words will accurately explain the character of the letter in question. It would be mere waste of space to reproduce Mr. Bessemer's letter in full. Its gist can be given in a very few words. Mr. Bessemer proposes the adoption of what we may term a steam mitrailleuse, as an adjunct to our national artillery; in other words, a steam Enfield rifle throwing a torrent of projectiles, mounted on a traction engine carrying a plentiful supply of bullets, and fitted with a mantlet to protect the gunner. There can be no doubt that such a weapon of offence and defence as Mr. Bessemer describes, if a possibility, would constitute a most valuable addition to the strength of any army; but unfortunately the thing as proposed by Mr. Bessemer is simply an impossibility, while his reasoning is from beginning to end based on the most erroneous notions, and betrays the greatest possible ignorance of certain mechanical truths, which we thought hitherto were well understood by the merest tyros in mechanical science.

Mr. Bessemer starts with the assumption that about 5 lbs. of coal and 3 gals. of water would exert force enough to raise 2,540 Enfield bullets to a height of one mile in a minute; which is probably true enough, though we have not checked his calculations, because it is unnecessary to do so. He assumes, furthermore, that a velocity of 1,900 ft. per second might be communicated to these 2,540 bullets by a current of steam, of 150 lbs. on the sq. in., flowing through a suitable tube. He admits, however, that it is possible the bullets might have a somewhat less velocity than that due to the rate of issue of steam of 150 lbs. on the sq. in., and modestly contents himself with 1,600 ft. per second, which is still, as he points out, considerably greater than that of a projectile fired from an Armstrong gun; and he finds a demonstration of the truth of his theory in the performance of a good steam fire engine. The details of his invention he prudently refrains from publishing, but he is quite ready to supply them, without fee or hope of reward, to the Government of this country.

There are two objections to Mr. Bessemer's scheme, which we shall consider separately. The first is that steam of 150 lbs. on the sq. in. could not possibly impart a velocity of anything approaching 1,900 ft. or even 1,600 ft. per second to an Enfield or any other bullet fired through a tube of practicable length. It will be admitted that what is true of an Enfield bullet in this matter must be true of any other projectile, larger or smaller. There can be no objection, then, to testing the accuracy of Mr. Bessemer's views by considering the case of a steam 32-pounder gun instead of an Enfield rifle, while there is the great advantage secured that we thereby eliminate fractions to a great extent—a matter of some importance in an article like this, written, not for mathematicians, but for every general reader who possesses some acquaintance with dynamics.

There is no principle more clearly laid down or better understood than this, that the effect produced on any given mass by a given force, bears a definite relation to the time of action of the force. In other words, a very small force acting for a long time may produce as much effect as a much greater force operating for a shorter time. We really owe an apology to our

readers for enunciating such a truism, but the statement is intended for Mr. Bessemer's benefit, which fact must be our excuse. Now let us see how it applies in the case of a steam gun. Let us suppose that we have a 32-pounder 21 ft. 4 in. long in the chase, and that the breech of this gun can be put into free communication by means of a short pipe 6.2 in. diameter, the same as the gun, with a gigantic steam boiler, in which is maintained a pressure of 150 lbs. to the sq. in.; we shall suppose that the ball fits steam tight but without any friction. The force brought to bear on it will then be $150 \times (6.2)^2 \times .7854 = 4{,}500$ lbs. in round numbers. Now if we suppose the ball to have a velocity of 1,600 ft. per second it will traverse the bore of the gun in the 75th part of a second. It is, therefore, evident that all the work which the steam can do upon it must be done in the 75th part of a second. We have then the following problem to solve: Given a weight of a little over 32 lbs., what force must be brought to bear on it during the 75th part of a second in order to impart a velocity of 1,600 ft. per second? If this force is greater than 4,500 lbs., then it is certain that our 32 lbs. ball cannot be driven from the gun with a velocity of 1,600 ft. per second by a force of 4,500 lbs. But if it cannot, Mr. Bessemer's reasoning must be erroneous. The required force can easily be ascertained by the well-known formula, $F\,t = m\,v$. Where F is the force, t the time of its action in seconds, m the mass of the body to be put in motion, an v the velocity. Let W = the weight of the ball, $32\frac{1}{6}$ lbs., $g = 32\frac{1}{6}$, F the required force, v the required velocity, m the mass of the ball, t the time of operation of the force. Then $m = \frac{32\frac{1}{6}}{32\frac{1}{6}} = \frac{W}{g} = 1$, and $F = \frac{m}{t}\,v = 1 \times 75 \times 1600 = 120{,}000$ lbs. Therefore, it follows that a force—if the force acts but the $\frac{1}{75}$ part of a second—of not less than 120,000 lbs. must act on a weight of $32\frac{1}{6}$ lbs. in order to impart to it a velocity of 1,600 ft. per sec. But the force which Mr. Bessemer can bring to bear is but 4,500 lbs. Therefore Mr. Bessemer's reasoning is completely erroneous.

In another form it may be stated that a velocity of 1,600 ft. per sec. could not be imparted to a $32\frac{1}{6}$ lbs. shot, by the operation of a force of 4,500 lbs., in less than 0.3 of a sec.; but $1{,}600 \times .3 = 480$ ft., which is the length of gun chase required. We fancy that Mr. Bessemer will hardly advocate the construction of a steam gun with a barrel 480 ft. long. It may be argued that, as the shot would not all at once acquire a velocity of 1,600 ft. per sec., the time during which the force would act would be prolonged, the bullet not passing through the whole length of the chase at 1,600 ft. per sec., but at some lower velocity, a mean between a speed infinitely small and 1,600 ft. per sec. Cheerfully granting this, Mr. Bessemer gains nothing. His gun barrel will, roughly speaking, admit of being cut down to a length of 240 ft., but if once we get beyond a length of chase of 20 ft. or so, it matters very little whether we stick on another 100 ft. or 100 yards. We need hardly stop to point out that all that we have said of a 32-pounder will apply with just as much force to an Enfield rifle bullet; the force and the weight may be estimated in ounces, or grains, or tons, but the numerical relations remain constant so long as the pressure of steam and the velocity remain unaltered. If a pressure of 150 lbs, on the sq. in. would suffice to impart a velocity of 1,600 ft. per sec., how is it, we may ask, that a pressure of 15 or 20 tons to the sq. in., due to the explosion of the powder charge, fails to impart a greater velocity than 1,200 ft. per sec., or thereabouts, to the projectiles fired from ordinary rifled guns?

We shall now consider the second objection to Mr. Bessemer's scheme. Let us suppose that the laws of nature are so far abrogated in his favor that a current of steam, moving at 1,900 ft. per sec., will really propel bullets at 1,600 ft. per sec. To do this he will admit that only 1 ball can be in the gun at the time. If a second is put in before the first is out the impelling force will be at once reduced in a way too obvious to need explanation. Therefore, the maximum number of balls which he could fire would be 75 per sec., and the quantity of steam used would be just one barrel full per bullet. It is evident, therefore, that the steam may be regarded as flowing from an orifice in the boiler at the rate of 1,900 ft. per sec., the orifice being of the same diameter as the bore of the gun. Let us suppose this, to use Mr. Bessemer's own figures, to be .6 sq. in., then the quantity of steam which the boiler must provide will be 13,680 cubic in. per

sec., 475 cubic ft. per min. 28,500 cubic ft. per hour. The volume of steam at 150 lbs. on the sq. in. is, water being unity, approximately 180, and $\frac{28,500}{180} = 158.3$ cubic ft. of water to be evaporated; in other words, Mr. Bessemer would have to provide a boiler of 160-horse power to maintain a constant current of steam of 150 lbs. pressure through a tube .6 of an inch in diameter. Such a boiler, we need hardly add, would weigh many tons, and would be quite out of place on the field of battle. Mr. Bessemer may, of course, get over the difficulty to some extent by reducing the number of bullets discharged in a given time, but even with this limitation it is evident that a boiler of great power must be provided if his steam gun is to prove even moderately efficient.

There are many other objections which can be brought against the scheme, but we shall not press them. The whole theory of the thing is defective from the very beginning, and is not only defective, but antiquated. Can it be possible that Mr. Bessemer never heard of Jacob Perkins' gun, which in a small way attained a certain amount of success with steam of 1,000 lbs. pressure on the sq. in.?

ON THE EFFICIENCY OF JET PROPELLERS.

By CAVALIERE E. BRIN, Director of Naval Construction, Ministry of Marine, Florence.

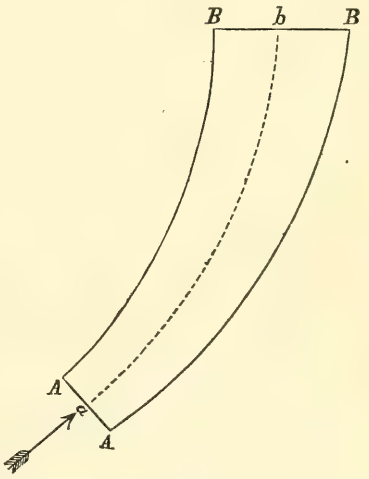
From "Journal of the Society of Arts."

1. Among the various plans for the propulsion of ships which have been proposed or tried, those in which the propelling force is produced by the reaction of one or more jets of water form a special category by themselves. Ruthven's hydraulic propeller applied first to the "Nautilus" and afterwards to the "Waterwitch, belongs to this class. The results obtained with it, so far as the amount of useful effect is concerned, were much more satisfactory in the latter vessel than in the former, but were nevertheless, very inferior to those given by the screw or paddle-wheel. Hydraulic propellers, in certain respects, offer some advantages, and might, under certain given circumstances, be preferred to any other. It has, consequently, seemed to me that it might not be altogether useless to investigate the theory of these propellers, with a view to ascertain if the low amount of useful effect obtained ought to be altogether attributed to the inherent defects of the system, or if it might not be remedied by the adoption of suitable arrangements.

2. In hydraulic propellers, the force of propulsion, that is to say, the thrust necessary to cause the ship to advance, is obtained, as I have already remarked, by the reaction of one or more horizontal jets of water, in a fore and aft direction; in other words, the propelling force is due to the action of a mass of water in motion upon the bounding surfaces of the vessel in which it moves.

Let A A, B B, be a receptacle in which a mass of liquid is in motion, and let A A be the inlet section of the liquid and B B that of its exit. Let it be supposed, too,

Fig. 1.



that the arrangements are such that we may assume all the small streams of water to have velocities which are equal and parallel both at their entrance and exit, and normal to the sections A A and B B; also that the motion has become uniform.

Let Ω_0 be the area of the section A A.
Ω_1 that of B B.
V_0 the velocity of the liquid at A A.
V_1 its velocity at B B.
P_0 P_1 the pressures on the extreme sections of the liquid at A A and B B.

α_0, β_0, γ_0, the angles which a normal to the section A A would make with the three orthogonal axes, x, y, z, the last being the vertical one.

α_1, β_1, γ_1, corresponding angles for the section B B.

X, the force impressed on the containing vessel in a horizontal direction, and parallel to x.

Y, the corresponding force impressed in a direction parallel to y.

Z, the vertical force impressed on the vessel —that is in a direction parallel to z.

π, the weight of the liquid contained in the receptacle A A, B B.

Q, the weight of a unit of volume of this liquid.

And g, the velocity impressed by gravity on heavy bodies in a unit of time.

By hydrodynamics, we have for the values of X, Y, Z:—

$$(1.)\ X = -\frac{Q\,\Omega_0^2\,V_0^2}{g}\left(\frac{\cos\alpha_1}{\Omega_1} - \frac{\cos\alpha_0}{\Omega_0}\right)$$

$$(2.)\ Y = -\frac{Q\,\Omega_0^2\,V_0^2}{g}\left(\frac{\cos\beta_1}{\Omega_1} - \frac{\cos\beta_0}{\beta_0}\right)$$

$$(3.)\ Z = -\frac{Q\,\Omega_0^2\,V_0^2}{g}\left(\frac{\cos.\ V_1}{\Omega_1} - \frac{\cos V_0}{\Omega_0}\right)$$

If the vessel A A, B B, have a rectilinear and uniform motion, and this is the case of the propellers of ships, the values of X, Y and Z remain constant.

3. If the inlet section of the vessel, A A, be immersed in the liquid, P_0 is the pressure of the exterior liquid on the plane, A A. Now, as it is required to find the force impressed on the vessel in directions parallel to the three axes, x, y, and z, we may observe that the pressures exerted by the liquid on the exterior immersed portion of the vessel are zero in a horizontal direction, and that no account must therefore be taken of the components $P_0 \cos\alpha_0$ and $P_0 \cos\beta_0$ in the values of X and Y, given by the equations (1) and (2).

With regard to the pressure P_1 on the section B B, this cannot be exerted without causing an equal and directly opposite pressure, either on the sides of the vessel or on the fastenings (in our case on the ship) to which it is fixed. Suppose, for instance, that this pressure is caused by a plunger, the rod of which is merely a prolongation of the piston-rod of a steam cylinder, then on the end of this cylinder there will be produced a pressure, P_1 equal and directly opposite to the pressure, P_1, exerted on the section B B of the liquid. Thus the pressure, P_1, will have no influence upon the horizontal thrusts exerted upon the system to which the vessel is fixed. Therefore, so far as concerns the horizontal thrusts produced by a mass of liquid in motion on the sides of a containing vessel, considered as propelling forces of the material system, of which this containing vessel forms a part, their value will be expressed by—

$$(4.)\ X = -\frac{Q\,\Omega_0^2\,V_0^2}{g}\left(\frac{\cos\alpha_1}{\Omega_1} - \frac{\cos\alpha_0}{\Omega_0}\right)$$

$$(5.)\ Y = -\frac{Q\,\Omega_0^2\,V_0^2}{g}\left(\frac{\cos\beta_1}{\Omega_1} - \frac{\cos\beta_0}{\Omega_0}\right)$$

4. This premised, let us consider an hydraulic propeller of the kind proposed by Mr. Ruthven. In this system, an hydraulic wheel or turbine, with its axis vertical, sucks in water from the sea through holes in the bottom of the ship, and this water is discharged through two horizontal pipes fixed on each side of the ship at the height of the load water-line. The openings in the bottom are so arranged that the water enters the ship from forward to aft, and in a horizontal direction.

We have thus a mass of water in motion in a vessel fixed in the ship, and the pressure, parallel to the direction of motion of the ship, sustained by the bounding surfaces of this vessel, will be the thrust that caused the propulsion.

If we take for the axis of x a horizontal line parallel to the middle line plane of the ship, and if we take for the positive direction that from the origin of coordinates to the bow of the ship, the amount of this thrust will be given by equ tion (4), in which Ω_0 and Ω_1 will be the areas of the orifices of supply and discharge, and V_0 and V_1 the velocities of the water as it passes these orifices; we shall have in this case—

$\alpha_0 = 180_0$, $\cos\alpha_0 = -1$; $\alpha_1 = 180_0$, $\cos\alpha_1 = -1$.

We shall therefore have—

$$(6)\ X_1 = \frac{Q\,\Omega_0^2\,V_0^2}{g}\left(\frac{1}{\Omega_1} - \frac{1}{\Omega_0}\right);$$

And as the volume of water which enters the ship must be equal to that which leaves it, we shall have—

$$\Omega_1 V_1 = \Omega_0 V_0 \text{ and}$$

$$(7.)\ X_- = \frac{Q\,\Omega_0 V_0}{g}(V_1 - V_0)$$

Calling M the unit of water discharged during a unit of time, we have—

$$(8.)\ X_1 = \frac{Q\,M}{g}(V_1 - V_0).$$

Let us call U the speed of the ship. The outside water is at rest, and on entering the ship is met by the water at the inlet section with a relative velocity of $U-V_0$.

At the inlet section, besides the pressure due to the hydrostatic head at this depth, there is a further pressure corresponding to that necessary to impress in a unit of time a velocity $U-V_0$ on a mass $\frac{Q\,M}{g}$. This pressure can be expressed by

$$\frac{Q\,M}{g}(U-V_0);$$

it is horizontal, and its direction is from forward to aft.

The final thrust sustained by the ship, and generated by the volume of water, M, which enters it in a unit of time and leaves it by the discharge pipes, that is to say, the force of propulsion, F, will therefore have for value:

$$F=\frac{A\,M}{g}\left\{V_1-V_0-(U-V_0)\right\} \text{ or}$$

$$(9.)\ F=\frac{A\,M}{g}(V_1-U).$$

Calling R the resistance offered by the ship to its progress through the water, we have F = R, and the work necessary to overcome the resistance, or the useful work in a unit of time, will be—

$$(10.)\ R\,U=\frac{A\,M}{g}(V_1-U)\,U.$$

5. Let us now seek to ascertain what will be the amount of work necessary to obtain this propelling force, F, and this useful work, R U.

We will retain the notation of section 4 with the following additions:

L_m, the work developed during a unit of time to produce the jets of water which serve to propel the ship.

V_a, the absolute velocity with which the water leaves the ship; we shall have $V_a = V_1 - U$.

h, the height of the orifices of discharge above the water section of the ship.

During a unit of time, a mass of outer water, $\frac{Q\,M}{g}$, which was at rest, enters the ship and leaves it with an absolute velocity, V_a, at a height, h, above its original level. There will thus be a *vis viva* acquired of $\frac{Q\,M}{g}V_a^2$, and a work expended of $Q\,M\,h$.

On this mass of water there acts the force of reaction of the sides of the vessel, along the length of which this mass of water moves, a force of reaction whose value as found above, is $\frac{Q\,M}{g}(V_1-U)\,U$. The work exerted during a unit of time to put this mass of water in motion, that is to say, the work of resistance, will therefore be:—

$$Q\,M\,h+\frac{Q\,M}{g}(V_1-U)\,U.$$

During the same period of time there has been transferred to this mass of water in motion a motive work, L_m.

If we neglect friction, the motive work, conformably with the principle of the conservation of *vis viva*, must be equal to the work of resistance

$$Q\,M\,h+\frac{Q\,M}{g}(V_1-U)\,U,$$

plus half the *vis viva* acquired, *plus* half the loss of *vis viva* occasioned by the shock given to the water on its entrance into the ship. During a unit of time, in consequence of this shock, a mass of water $\frac{Q\,M}{g}$ changes its velocity suddenly from U to V_0; the velocity lost in this shock is therefore $U-V_0$, and the loss of *vis viva* is $\frac{Q\,M}{g}(U-V_0)^2$. The principle of the conservation of the *vis viva* next gives us the following equation :—

$$L_m=Q\,M\,h+\frac{Q\,M}{g}(V_1-U)\,U+\frac{Q\,M}{g}\frac{V_a^2}{2}+\frac{Q\,M}{g}\frac{(U-V_0)^2}{2}.$$

But by equation (9) we know that

$$\frac{Q\,M}{g}(V_1-U)=F=R.$$

We therefore have—

$$(11.)\ L_m=R\,U+Q\,M\,h+\frac{Q\,M}{g}\frac{V_a}{2}+\frac{Q\,M}{g}\frac{(U-V_0)}{2}$$

The first term of the second member of this equation represents the work necessary to overcome the resistance of the ship, or the useful work. It therefore follows that the actual work expended in this hydraulic propeller must be equal to the useful work, *plus* the work necessary to raise the amount of water employed to the height of the discharge pipes above the water-line, *plus* one-half of the *vis viva* acquired by the water

when it leaves the ship, *plus* one-half of the loss of *vis viva* arising from the shock encountered by the water on its entrance into the ship.

We might, therefore, have written down this equation at once from *a priori* considerations. The first term of the second member of this equation representing, as we have said, the useful work, all the other terms represent losses of work.

It will then be necessary so to arrange matters as to make these terms zero, or else to render them as small as possible.

The term $Q\,M\,h$ will be zero when $h = 0$, which shows us that it is of advantage to place the discharge pipes at the load water line or below it.

The term $\frac{Q\,M}{g}\frac{(U-V_0)^2}{2}$ will be zero when $U=V_0$; while the term $\frac{Q\,M}{g}\frac{V_a^2}{2}$ will be zero when $V_a = 0$; that is, if the water left the ship without any velocity at all. But we must observe that $R = \frac{Q\,M}{g}V_a$, so that it is impossible to make $V_a=0$, since in this case we should require an infinite amount of water, and inlets and outlets of infinite size. Take $V_a = a\,U$, and suppose that the conditions pointed out above for rendering the other losses of work zero have been satisfied, we shall have

$$L\,m = R\,U + \frac{Q\,m}{g}\,a^2\,\frac{U^2}{2}$$

and

$$R = \frac{A\,M}{g}\,a\,U;$$

whence we obtain

$$L\,m = R\,U\left(1+\frac{a}{2}\right)$$

and the coefficient of useful effect of the motive work will be

$$U_t = \frac{R\,U}{a\,U} = \frac{2}{2+a}$$

If $a = 1$ (as in the "Waterwitch") we shall have $U_t = 0.66$.

6. If the openings by which the water enters the ship, instead of being arranged as in the "Waterwitch," were so contrived that the water came into the ship in a direction contained in a plane perpendicular to the middle line plane of the ship, the outside water, in that case, which is at rest when it enters the ship, would receive a shock with the velocity, U, of the ship; it would therefore produce an increase of resistance, of which the value would be $\frac{Q\,M}{g}U$, and there would be a loss of *vis viva* equal to $\frac{Q\,M}{g}\frac{V^2}{2}$.

The value of the horizontal thrust produced by the water in motion would be given by the equation (4) on making

$a_0=90°$, $\cos a_0=0$; and $a^1=180°$, $\cos a_1=-1$.

We should, therefore, have—

$$X = \frac{Q\,M}{g}V_1.$$

This thrust ought to be equal to the resistance of the ship *plus* the increase of resistance indicated above. We shall then have—

$$\frac{Q\,M}{g}V_1 = R + \frac{Q\,M}{g}U;$$

whence we get

$$R = \frac{Q\,M}{g}(V_1 - U)$$
$$= \frac{Q\,M}{g}V_a$$

The resisting work overcome, that is to say, the useful work will be—

$$R\,U = \frac{Q\,M}{g}U\,(V_1 - U)_1$$
$$= \frac{Q\,M}{g}U\,V_a.$$

The principle of conservation of *vis viva*, by considerations similar to those set forth in section 5, leads us directly to the following equation—

$$L\,m = R\,U + Q\,M\,h + \frac{Q\,M}{g}\frac{V_a^2}{2} + \frac{Q\,M}{g}\frac{U_2}{2}$$

We shall see immediately that we ought to make $h = 0$.

If we take $V_a = a\,U$, we shall have—

$$L\,m = R\,U + \frac{Q\,M}{g}\frac{a^2\,U^2}{2} + \frac{Q\,M}{g}\frac{U_2}{2}$$

We have—

$$R = \frac{Q\,M}{g}V_a$$

which gives

$$L\,m = R\,U\left(1+\frac{a}{2}+\frac{1}{2\,a}\right)$$

and the coefficient of useful effect of the motive work will be—

$$U_t = \frac{1}{1+\frac{a}{2}+\frac{1}{2\,a}}$$

If $a = 1$
$U_t = 0.50$

We see, therefore, that this arrange-

ment is less advantageous than the preceding. Such an arrangement was adopted in a steamboat constructed by Cockerill's Company, which was exhibited at the Paris Exhibition of 1867.

7. Let us suppose, now, that the openings in the bottom of the ship are arranged in such a manner that the water enters in a direction horizontal and parallel to the middle line plane, and from aft forward.

In this case, the thrust exerted by the body of water in motion will be given by equation (4) on making

$$a_0 = 0,\ \cos a_0 = 1;\ a_1 = 180^0,\ \cos a_1 = -1.$$

We shall then have—

$$(12.)\ X = \frac{Q\,\Omega_0^2\,V_0^2}{g}\left(\frac{1}{\Omega_1}+\frac{1}{\Omega_0}\right) = \frac{Q\,M}{g}(V_1 - V_0).$$

This value of X represents the force of propulsion F, and we shall have—

$$(13.)\ F = R = \frac{Q\,M}{g}(V_1 + V_0)$$

8. With regard to the work required in order to obtain this force of propulsion, it may be determined by considerations similar to those set forth in section 5.

We will use the same rotation as that adopted in the preceding sections.

In a unit of time—

The *vis viva* acquired will be $\frac{Q\,M}{g}V_a^2$.

The motive work developed, L_m.

The work of resistance due to gravity, $Q\,M\,h$.

The work of resistance due to the reaction of the surface of the channels along which the water moves,

$$X\,U = \frac{Q\,M}{g}\,(V_1 + V_0)\,U.$$

We shall therefore have

$$(14.)\ L_m = \frac{Q\,M}{g}\frac{V_a^2}{2} + Q\,M\,h + \frac{Q\,M}{g}\,(V - V_0)U.$$

or as

$$R = \frac{Q\,M}{g}(V_1 - V_0).$$

$$(15.)\ L_m = R\,U + Q\,M\,h + \frac{Q\,M}{g}\frac{V_a^2}{2}$$

The first term of the second member of this equation represents the useful work; all the others injurious work.

We must therefore make—

$$h = 0$$
$$V_a = 0$$

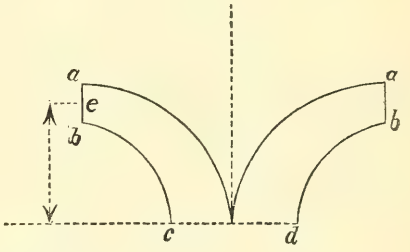
Having satisfied these conditions, we shall have

$$L_m = R\,U,$$

and the coefficient of useful effect, $U_e = 1$. That is to say, the motive work will equal the work of resistance. This propeller should, therefore, be theoretically perfect.

9. It is now necessary to determine what conditions must be satisfied by the hydraulic machine which has to set the water in motion and discharge it from the ship, so as to utilize the motive power as perfectly as possible. For this purpose we may employ one of the numerous hydraulic machines for raising water. But as it is required to produce continuous jets, and to avoid intermission, as well as to set in motion very considerable bodies of water, there can be no doubt that centrifugal pumps or turbines constitute in this case the best form of hydraulic machine to employ.

Fig. 2.



Let us call

T, the moving force transmitted to the shaft of the turbine in a unit of time.

V, the velocity of the extremities of the vanes of the turbine (if u is the angular velocity).

R, the radius of the turbine.

N, the number of revolutions of the turbine in a unit of time: so that

$$V = R\,u = \frac{2\,\pi\,N\,R}{60}.$$

H, the height of the centre, e, of the extremities of the vanes above the section, $c\,d$, of the inlet of water into the turbine.

H_1, the height of the orifices of discharge above the point e.

P, the height of the column of water which measures the pressure at the section, $c\,d$, of the inlet of the water into the turbine.

v, the velocity of the water at the section $c\,d$.

For the remainder we will adhere to the notation of the preceding sections.

If we disregard the friction and the loss of work due to throttling, sharp turns,

and so forth, the work, T, ought to be equal to that necessary to raise the weight Q M to the height $H + H_1 - P$, *plus* the work corresponding to one half the *vis viva*

$$\frac{Q\,M}{g}(V_1^2 - v^2)$$

acquired by the water, from its entrance into the turbine until it leaves the orifices of discharge, *plus* also the work corresponding to one-half the losses of *vis viva* that take place in this kind of hydraulic machine, and which are:—

$\frac{Q\,M}{g}a^2$, on the entrance of the water into the turbine, where a is the velocity lost in the entering.

$\frac{Q\,M}{g}b^2$, on the exit of the water from the turbine, where h is the absolute velocity with which it leaves the turbine.

We shall therefore have

$$(16.)\quad T = Q\,M\,(H + H_1 - P) + \frac{Q\,M}{g}\frac{V_1^2}{2} - \frac{Q\,M}{g}\frac{v^2}{2} + \frac{Q\,M}{g}\frac{a^2}{2} + \frac{Q\,N}{g}\frac{b^2}{2}.$$

The loss of *vis viva* $\frac{Q\,M}{g}\frac{a^2}{2}$ on the entrance of the water into the turbine, may be almost entirely obviated by making the vanes of a suitable shape; we shall therefore neglect it.

Let us put

$$(17.)\quad H + H_1 - P + \frac{V_1^2}{2g} - \frac{v^2}{2g} = \frac{\mu^2}{2g}.$$

$\frac{\mu^2}{2g}$ will represent the column of water which the turbine has to take up, and $Q\,M\,\frac{\mu^2}{2g}$ the useful work in a unit of time.

We shall have

$$(18.)\quad T = Q\,M\,\frac{\mu^2}{2g} + \frac{Q\,M}{g}\frac{b^2}{2}.$$

The term $\frac{Q\,M}{g}\frac{b^2}{2}$ represents a loss of work; we ought, therefore, to diminish this term or the velocity, b, as much as possible.

Let us determine this velocity.

The relative motion of the water in the turbine is determined by the pressures at the inlet section, $c\,d$, and by those at the outlet, $a\,b$, by gravity and by the centrifugal force.

Let v_1 be the relative velocity acquired by the water on its exit from the turbine under the action of these forces. The work developed by these forces in a unit of time will be—

1st. That of the pressure at the entrance will be $Q\,P\,\omega\,U$, ω being the area of the section through which the water enters the turbine, and U the relative velocity of the water at this section.

Now we have $\omega\,U = M$, so that the work done by this force will be $Q\,P\,M$.

2d. That of the pressure upon the orifices of discharge of the water from the vanes of the turbine will be $Q\,P_1\,M$.

3d. The work done by gravity will be $Q\,M\,h$.

4th. With regard to the work done by the centrifugal force, we know that the work transmitted by this force to a body $\frac{Q\,M}{g}$ which, having a rotary motion of which the angular velocity is ω, starting from rest, moves off from the axis to a distance, R, has for its expression

$$\frac{Q\,M}{g}\frac{\omega^2\,R^2}{2} = \frac{Q\,M}{g}\frac{V^2}{2}.$$

The principle of the conservation of *vis viva* then leads to the following equation:—

$$Q\,P\,M - Q\,P_1\,M - Q\,M - + \frac{Q\,M}{g}\frac{V^2}{2} = \frac{Q\,M}{g}\frac{v_r^2}{2}$$

whence we have

$$P - P_1 - H + \frac{V^2}{2g} = \frac{v_r^2}{2g}.$$

The velocity V_1 of the water at the orifices of discharge will be due to the height $P_1 - H_1$. We shall therefore have

$$\frac{V_1^2}{2g} = P_1 - H_1 \text{ and } P_1 = \frac{V_1^2}{2g} + H_1$$

which gives us

$$\frac{v_r^2}{2g} = P - \frac{V_1^2}{2g} - H_1 - H + \frac{V^2}{2g}$$

that is to say

$$\frac{v_r^2}{2g} = \frac{V^2}{2g} - \frac{\mu^2}{2g}$$

Whence we derive

$$v^r = \sqrt{V^2 - \mu^2}$$

The velocity of the water, v, which it will have when it quits the turbine, will be the resultant of V, the velocity of the ends of the vanes, and of the relative velocity v_r of the water tangentially to the ends of the vanes.

Calling e the angle which the tangent to the ends of the vanes makes with the outer circumference of the turbine, we shall have—

$$(19)\quad v^2 = v_r^2 \sin^2 e + (V - v_r \cos e)^2.$$

We have seen that it is necessary to endeavor to render v a minimum; with this object we must make $e = 0$.

We shall then have

$$b^2 = (V - v_r)^2 - (V - \sqrt{V^2 - \mu^2})^2$$

In order to get rid of the velocity v, it would be necessary to have $V = \infty$, whence we see that it is impossible to overcome the loss of momentum $\frac{Q\,M}{g} v_1^2$ and that it is an advantage to make the turbine revolve with a great velocity.

If we substitute the value of v^2 found above in the equation, which gives us the expression of the motive work, we shall obtain the following equation:

$$(20.)\quad T = Q\,M\frac{\mu^2}{2g} + Q\,M\frac{(V - \sqrt{V^2 - \mu^2})^2}{2g}$$

The term $Q\,M\frac{\mu^2}{2g}$ represents, as we have said, the useful work obtained by the turbine, so that the coefficient of useful effect of the motive work will be—

$$U_t' = \frac{\mu^2}{\mu^2 + (V - \sqrt{V^2 - \mu^2})^2}$$

This coefficient can only become unity when $V = \infty$.

If we make $V = \mu$, we shall have $U_t' = 0.50$.
" $V = 1.25\,\mu_1$ " $U_t' = 0.80$.
" $V = 2\,\mu$ " $U_t' = 0.93$.

But practically we cannot make the angle e vanish, that is to say we cannot arrange the ends of the vanes tangentially to the outer circumference of the turbine, for if we did so the water which leaves one vane would strike the following.

We cannot make $e = 20°$ as in good centrifugal pumps; then we shall have—

$$v^2 = v_r^2 \sin^2 20° (V - v_r \cos 20°)^2.$$

In this case the coefficient of useful effect will have for value—

$$(21.)\quad U_t' = \frac{\mu^2}{\mu^2 + (V^2 - \mu^2)0.12 + (V - V\sqrt{V^2 - \mu^2} + 0.94)^2}$$

If we make $V = 2\,\mu$, we shall have $U_t' = 0.71$.

This theoretical coefficient of useful effect cannot be practically attained. It is impossible to make the term $\frac{Q\,M}{g}\frac{a^2}{2}$ zero in relation to the entrance of the water into the turbine. It is also necessary to take account of all the losses of *vis viva* arising from throttling angles and friction during the passage of the water, from its entrance into the ship to its exit.

Having regard to these different causes of loss of worth, the practical coefficient of useful effect, U''_t, will be some fraction of the theoretical one.

We shall therefore have

$$U''_t = A\,U'_t,$$

A being a constant coefficient, the mean value of which, judging from what is generally the case in hydraulic machines, may be taken at 0 85.

10. In order to obtain the final coefficient of useful effect of this propeller, it will be necessary to multiply U_t, of which we have spoken in sections 5, 6 and 7, by the coefficient of useful effect belonging to the hydraulic machine, so that this final coefficient of useful effect will be

$$U'''_t = U_t \times U''_t = U_t \times A\,U''_t.$$

In each particular case we shall adopt for these values of U_t and U'_t those found above.

If we adopt the arrangements referred to in section 5, which are those of the "Waterwich," and if the velocity of discharge V_1 of the water be double that of the ship, we shall have $U_t = 0.66$, and if for the turbine we make such arrangements as to have the maximum effect, and if we have $V = 2\,\mu$, we shall have a final coefficient. $U''_t = 0.66 \times 0.85 \times 0.81 = 0.45$, which is a very low useful efect, and inferior to that obtained with the screw and the paddle-wheel.

With the arrangement referred to in section 6, this coefficient would be lower still.

The most favorable arrangement is that referred to in section 7. We can in this case obtain a useful effect $U_t = 1$, and a final useful effect (with $V = 2\,\mu$),

$$U''_t = 1 \times 0.85 \times 0.71 = 0.60.$$

This coefficient of useful effect is about the same as those realized by the screw-propeller and the paddle wheel.

11. Recapitulating, we arrive at the following conclusions:

In order that an hydraulic propeller may act under good conditions, it is necessary to arrange things so as to insure:

a. 1st. That the water shall enter the ship in a horizontal direction, and parallel to the middle line plane, and from aft to forward.

2d. That the orifices of discharge shall be situated either at the level of the load water line or below it.

3d. That the water shall leave the orifices of discharge in a horizontal direction and parallel to the middle line plane of the ship, and shall have a relative velocity equal to that of the ship, that is to say, an absolute velocity equal to zero.

b. With regard to the hydraulic machine employed to draw the water from the sea and discharge it from the ship, that, if we make use of a turbine, the vanes shall have to be curved in such a manner that the water shall enter the turbine without shock, and that the ends of the vanes shall make a very acute angle (about 20°) with the outer circumference of the turbine.

It is necessary, also, that the turbine shall revolve rapidly, so as to have a very high velocity at its outer circumference.

These conditions being satisfied, we can obtain with hydraulic propellers a mean coefficient of 0.60.

12. The "Waterwitch" has been fitted with an hydraulic propeller, of which we know the results.

We will proceed to examine if these accord with the theory set forth in the preceding sections.

In the "Waterwitch," we have :—*

Area of the orifices of discharge—

$$\Omega_1 = 6 \text{ sq. ft.} \overset{m}{=} 0.5538.$$

Velocity of discharge of the water—

$$V_1 = 30 \text{ ft.} \overset{m}{=} 9.135.$$

Volume of water discharged in a second—

$$M = 5059 \text{ litres.}$$

Area of immersed midship section—

$$B^2 \overset{m}{=} 31.85.$$

Speed of ship.

$$U = 15 \text{ ft.} \overset{m}{=} 4\ 57 = \frac{V_1}{2}.$$

$$V_a = V_1 - U = U = 4.57.$$

Area of the openings admitting the water into the ship—

$$\Omega_0 = 30 \text{ sq. ft.} \overset{m}{=} 2.769.$$

* These data are taken from newspaper articles and engravings, and are perhaps not altogether exact. With more correct data we should be able to correct the calculations.

Velocity of the water on its entrance into the ship—

$$V_0 = \frac{V_1}{5} = \frac{2\,U}{5}.$$

In the "Waterwitch," the openings by which the water is admitted into the ship open forward, and the water enters them horizontally.

This is the case considered in section 4; and we therefore have $R = \frac{Q\,M}{g}(V_1 - U)$, which gives us for the "Waterwitch," R = 2,402 kilogrammes.*

The work required to propel the "Waterwitch," (independently of the losses of work due to the hydraulic machine itself), will be given by equation (11) of section 5. We shall therefore have

$$L_m = R\,U + Q\,M\,h + \frac{Q\,M}{g}\frac{V_a^2}{2} + \frac{Q\,M}{g}\frac{(V - V_0)^2}{2}$$

For the "Waterwitch," we have

$$h = 0;\ V_a = U;\ V_0 = \frac{2}{5}\,U,$$

and as

$$R = \frac{Q\,M}{g}(V_1 - U)$$

$$= \frac{Q\,M}{g}\,U.$$

From which we get

$$\frac{Q\,M}{g} = \frac{R}{U}.$$

On substituting this value of $\frac{Q\,M}{g}$ in the above equation, we shall have

$$L_m = R\,U\,(1 + \tfrac{1}{2} + \tfrac{9}{50})$$

we shall have

$$= R\,U \times 1.76.$$

The coefficient of useful effect would therefore be $U_t = 1.57$.

We see that the greater portion of the loss of work arises from the too great velocity of the water when it quits the ship. The above coefficient is still further reduced by the losses of work due to the hydraulic machine or turbine.

In the "Waterwitch" the vanes of the turbine, instead of being curved and ar-

* Assuming that the resistance of ships is proportional to the immersed surface of the midship section, and to the square of the velocity, we shall have $R = K\,B^2 V_2$, where K is a constant. If we make R = 2,402 kilogrammes for the "Waterwitch," we find that K. =361. This value of K agrees with the admitted value of this coefficient in ships of the size and fineness of lines of the "Waterwitch," which shows the correctness of our theory. It may be observed that, with this system of propulsion, it is very easy to determine the resistance of ships without having recourse to dynamometers.

ranged so that the water shall quit them in a direction almost opposite to that of the rotation of their extremities, that is to say, with a very low absolute velocity, have their ends normal to the outer circumference of the turbine.

Under these conditions, the absolute velocity (b) with which the water quits the turbine will be given by equation (19) when we make $e = 90°$. We shall then have

$$b_2 = v_r^2 + V^2$$

and as

$$v_r = \sqrt{V^2 - \mu_2}$$

we shall have

$$b^2 = 2V^2 - \mu^2.$$

This value of b^2 being substituted in the equation (18) we shall have

$$T = \frac{Q\,M}{2\,g}\,2\,V^2.$$

The useful work is $Q\,M\,\frac{\mu_2}{2g}$ as we have observed in section 9.

The theoretical coefficient of useful effect for this turbine will therefore be

$$U'_t = \frac{\mu^2}{2\,V^2}.$$

In the "Waterwitch," we have:—

D, the diameter of the turbine = 4.27 m.

Number of revolutions per minute, N = 42.

We have, therefore $V = 9.50\ m$.

The area of the sections of discharge through which the water quits the turbine is about 80 sq. ft. We have, therefore, $V_r = 0.68\ m$., and as we have $V_r^2 = V^2 - \mu^2$, we get $\mu^2 = 90$. We have therefore—

$$U'_t = \frac{\mu^2}{2\,V^2} = \frac{90}{2\,(9.50)^2} = 0.50.$$

The final coefficient of useful effect in the "Waterwitch" would therefore be—

$$U''t = U_t \times A\,U'_t = 0.57 \times 0.85 \times 0.50 = 0.24,$$

a very low coefficient, and one which must be attributed to the arrangements adopted for their propeller itself, with which we have a useful effect of 0.57, and for the hydraulic machine, with which we have a useful effect of 0.50.

These theoretical results agree with those realized in practice.

In the trials of the "Waterwitch" in which the above results have been obtained, an indicated horse power of 828 was realized.

The resistance, R, of the "Waterwitch" being 2,402 kilogrammes, and the speed 4.57 m. per second, the work developed by this resistance in horses of 75 kilogrammètres is 147.

The coefficient of useful effect will therefore be $\frac{147}{828} = 0.18$. By assuming the value 0.24, found above as the coefficient of useful effect of the propeller, we should have as the coefficient of useful effect of the engines $\frac{0.18}{0.24} = 0.75$, which is a probable coefficient for a marine steam engine.

The results obtained in practice agree therefore with those deduced from theory.

13. Let us now endeavor to ascertain what results might be arrived at in the "Waterwitch," by fitting this ship with a hydraulic propeller arranged as pointed out by theory.

The openings by which the water enters should be turned towards the stern of the ship; and we ought to have $V_a = V_1 - U = O$; that is, $V_1 = U = 4.57$.

We have

$$R = \frac{Q\,M}{g}\,(V_0 + U_1)$$

$$= \frac{Q\,M}{g} V_1 \left(\frac{2}{5} + 1\right).$$

And

R = 2,402 kilogrammes.

We shall find from this, that the amount of water to be discharged in a second, M, should be equal to 3,500 litres.

The area of the orifices of discharge must then be

$$\Omega_1 = \frac{3500}{4.57} = 0.76^m.$$

With such arrangements we should have, as seen in section 5, a coefficient of useful effect of the propeller equal to unity.

With regard to the hydraulic machine itself, by arranging it as explained in section 9, we are able to realize a coefficient of useful effect $U_1 = 0.71$, so that we should have a final coefficient of useful effect of $0.85 \times 0.71 = 0.60$, instead of 0.24, as in the "Waterwitch" with her present arrangements, that is a useful effect exceeding that obtained in the "Waterwitch" in a ratio of 2.50 to 1.

Instead of having 828 horses' power indicated by the engines, it would be sufficient to realize 331. As we have already seen, this advantage may be obtained by

making the area of the section of the orifice of discharge 0.55 instead of 0.76. But the quantity of water to pass through would be less, that is to say, 3,500 litres per second, instead of 5,000; so that by using a higher velocity the turbine might be made smaller, and the machinery lighter.

SMALL-GAUGE RAILROADS.*

By ALFRED F. SEARS, C. E.

The utter isolation of regions not possessing the advantages of the railroad, which are accounted essential to a wholesome civilization, has led to many devices among engineers by which the use of this instrument of modern progress may be made more accessible to poor and remote communities.

In this country, as in England and some of the Continental kingdoms, the railroad is becoming the common highway of the people; so that, to live off a line of railroad is no longer to be in the living world, but buried in an out-of-the-way place.

In the countries of Northern Europe—in Norway, Sweden and Russia—where a few lines exist, but no complete systems, the Governments have turned their attention to the business and appointed boards of commissioners who have investigated the railroads of the world, to report the cheapest and make such suggestions for reducing their cost as shall place the possession of extended systems within reach of their respective Governments; and in accordance with the same general demand, American engineers have been invited to India because they build cheap railroads.

The problem is reaching, indeed has reached, a happy solution in the adoption of lines of very much narrower gauges, steeper gradients and sharper curves. Lines on which the cars and engines are all smaller and lighter than has been common.

These systems have ceased to be experimental; on the contrary, so successful have they been, that even in the United States, where railroads are built the cheapest, the public attention is being drawn to them, and prudent men are asking why every section may not have its railroad when they can be provided at such cheap rates?

I have long been impressed with the opinion that we are spending more money in the first cost of railroads than is necessary; and accordingly, in my estimates for the construction of this road, I have reduced the width of the road-bed and introduced temporary expedients, to save building with borrowed money, so that I have been able to cut down the cost of the work, below the average of railroads in this section, more than $3,000 per mile.

I apprehend that but few persons state the correct problem to themselves when they proceed to build a railroad. They ask, *How much money can be commanded* for the work? Whereas they should rather ascertain, *What is the least amount* for which an object can be properly attained?

The common statement of the question thus corrected in our case would probably be, What is the least sum for which a railroad can be built between our termini?

We have given, a certain amount of terminal business to be moved along or across the country, and a certain section to be accommodated with as good means of transportation from point to point as the highest requirements of the best condition of a farming community demand. What is the cheapest method by which this duty can be properly accomplished?

Such method of transportation will, of course, be a railroad on which the traffic is done with steam. But, is it essential that we build such a road as the New York Central or the Erie? Shall we build the ordinary railroad with the ordinary cars, simply because we have become accustomed to them, without considering the necessities of the case? If the experience with such a road proves it to be the cheapest and as remunerative as we have any right to expect from the transaction of the business in hand, then it is undoubtedly the best thing to be

* Extracts from a report to the Board of Directors of the Pennsylvania and Sodus Bay Railroad Company.

done. If it is the best to be had without resorting to experiment, then we should adopt it.

But, under existing circumstances, seeing that the railroad has been so improved in the last few years as to insure positive and large dividends at lower rates of charge for transportation, there seems to be good reason why we should examine the new methods and ascertain if they contain anything of practical value to us.

In this paper I propose to show,

First.—Some reasons why railroads, although paying dividends, for they generally do, are not as remunerative at cheap rates as they should be ; and why, also, they are not as valuable property to the unspeculating investor as they may be.

Second.—The changes in the system by which they have been made a safe investment, and placed within the reach of every fairly settled section of country.

Third.—The application of the system to our uses and the cost of its construction, with some estimate of its work, compared with the present methods of building roads.

I.—The dividends of railroads are cut down, while the charges of doing the work are increased, by constant drainage on the income of the companies to pay interest on borrowed money, which has been invested in extravagant construction. In a paper just prepared for the American Society of Civil Engineers, I have treated this subject in some detail, drawing my illustrations from the line of road we are about constructing. I ask your indulgence while I refer to a single instance in support of the proposition I have made.

It is customary in this region to build the road-beds of railroads uniformly 18 ft. wide in excavation, and 14 ft. wide in embankment, without reference to the position of the work, whether a light bank or a heavy one ; whether the cut is shallow, through a level plain, deep under a side-hill or containing a steep grade that will assist in draining it.

The banks, also, are built of uniform width, without reference to the question of height, although a slope 20 ft. long is exposed to 210 times the liability of damage by corrosion that is suffered by a slope 1 ft. long.

Again, it is customary to say of massive structures in wood, that "decay outruns interest," and that the true economy is to build a permanent work in the beginning.

I find it otherwise, and I apply to the railroad only the simplest rules of practice. In this section of country we witness to-day among the farmers many elegant homes ; our thrifty citizens in the country live in houses that would be ornamental in a wealthy village ; but these houses have grown like the trees under whose shade they stand. Beginning two or three generations ago in the humble log cabin or hemlock shanty, they have advanced through the intermediate stages of the wood-colored frame and the pretty white cottage with its green blinds and little front porch.

These splendid farms were begun with the tillage of 15 or 25 acres, just as the settler had one or more grown sons to assist in the work.

Is there a successful manufacturer among you who began life in any other way? Apportioning his shops to his means, he has grown each year, and if he is able now to do an extensive business and build great factories, it is because he has *grown* instead of *swelling*, so that he has become rooted and strong with increasing dimensions, instead of thinly expanding to collapse with a fizz.

I would have us remember this principle in building railroads. So, by reducing the width of road-beds and making the slopes of cuts steeper than is common, and erecting temporary wooden trestles in place of permanent banks and expensive masonry, I have been able to cut down the first cost of this work $290,000, after counting a shrinkage of 10 per cent. on the negotiation of bonds ; and this estimate contemplates a road of the ordinary gauge. Now all these permanent features may be inserted in the work after trains begin to run at a greatly reduced figure.

By saving to ourselves this capital of $290,000, we have its annual income at 7 per cent., or $20,300, to devote to the work of completion. In 7 years all our slopes will have been dressed by the weather and removed by gravel trains ; while in 10 years the wood-work in the deep ravines will have been superseded by banks and the necessary masonry, and our original capital will be released to us for other purposes. We shall have ex-

pended $203,000 for work that would originally have cost us $290,000. Nor is this sum the limit of expenditure. For 20 years we shall have been paying 7 per cent. interest for the money to inexorable bond-holders, and, at the end of that time, the principal.

20 years' annual payment of $20,300 is..	$406,000
And then the original capital.....	290,000
A total of.....	$696,000

Or 3½ per cent. per annum on our original capital stock, draining away from the earnings of the road to pay for useless works.

The dividends of railroads are further cut down by the immense amount of non-paying weight carried by trains. It is estimated that the great express passenger trains of the country, with their cumbrous drawing-room and palace cars, transport 3,000 lbs. of dead weight per passenger; a labor into which they are forced by the competition of rival lines. Although extra charges are made for these luxuries, it is a mistake to suppose that passengers pay for the extra work; on the contrary, they are an onerous burden on every company which furnishes them.

Our road will escape this tax, but it must meet another. If you ride all day on any way train of the country you will observe that the passenger cars reserved for the accommodation of local traffic on roads through the least settled sections, are but partially filled during many hours of the day. An average, equivalent to 30 through passengers per car, is reckoned good work on the principal lines, and these trains move with about 6 passenger cars, weighing, with engine, loaded tender and baggage van, 360,000, or 2,000 lbs. per passenger. That is to say, for every ton of passengers that pays we carry 15 tons of dead weight without pay.

Last year the passenger traffic of the New York Central amounted to 206,000,000 passengers carried 1 mile; but they carried 306,250,000 tons of dead weight with with them, *i. e.*, 1½ tons of dead weight per passenger, exclusive of the weight of baggage.

The Erie did worse than this. They carried 128,500,000 passengers 1 mile, with 425,500,000 tons of dead weight; which is 3½ tons of dead weight per passenger.

In the freight traffic, the Central moved 474,500,000 tons 1 mile with 410,700,000 tons of dead weight, or 9–10 of a ton of dead weight for every ton of paying freight; while the Erie moved 818,000,000 tons of freight with 1,083,333,000 tons of dead weight, or 1⅓ tons of dead weight per ton of paying freight.

The old stage coach did nothing so bad as this. A Concord stage that carried seventeen passengers and a driver, bore, with its baggage, about 3,400 lbs. of non-paying weight, or 200 lbs. per passenger; that is, for every ton of passengers it carried but 1⅓ tons of dead weight.

So, too, our lumber wagons carry but ⅓ of a ton of dead weight for every ton of paying load.

It is true that an increased strength is demanded for the high speed of a railroad train; and also to transmit power through individual cars to move an entire train, as well as for the concussion received by stopping trains. But all these circumstances fail to constitute reasons for doing work that does not pay; and whatever dividends we get from a road, the carriage of unnecessary dead weight certainly does not pay.

What I have said is sufficient to illustrate the proposition with which I started, of which every railroad man is aware, and every investor painfully sensible.

Were there no way out of this condition of things, we might reasonably be discouraged in our attempt to build a road that shall escape the general disappointment of hopes.

When we build canals our custom is to ascertain, as near as may be, the amount of traffic we are to accommodate, and apportion the width and depth accordingly. All our private enterprises are conducted on the same principle; but when we build railroads we seem to take leave of our ordinary wits. We say, "The New York Central, or some other, is a good road," and so taking that for a model, we build through the agricultural districts, where we shall run for the first year not more than 8 trains a day, a road costing as much as one that passes a train every half hour; that is to say, a road is built and stocked that our traffic demands the use of it for less than 1 hour in the 24, and during the remainder of the time, or during 11½ months of the 12, the whole of this immense capital is lying idle. Is there any other business,

known among men, that is done in the same stupid way?

The first proposition, then, is to build, as nearly as possible, a road that will be worked well up to its capacity, with a traffic, the reasonable increase of which will require an increase of capacity.

Such a road will accommodate 2 trains in the hour each way, and if worked with a telegraph will be as safe as any double track line in existence.

As to the luxury and spaciousness of cars and speed of trains, I am satisfied that our accommodations should be arranged and our road worked for the great paying business and middle classes, instead of for the less numerous, more fastidious and more exacting wealthy pleasure seekers.

II.—A road to answer all our requirements will be found in the class known as Small Gauge Railroads, which are now exciting the popular and professional mind of this country and Europe.

In this connection, as touching the question of gauges, it is an interesting fact, that the Great Western English line, and other broad gauge roads in America, are getting rid of their systems as rapidly as possible. They have been laying a third rail, of the ordinary gauge (4 ft. 8½ in.), for which alone they buy rolling stock. When the plant on hand, adapted to the broad gauge, shall have been exhausted, one of the original rails will be removed, and those roads will become one with the system generally in vogue. Such a result on the part of those great works proves a very important fact. They have made all the expenditure necessary for broad gauge lines, and have built permanent works for such lines. These they are abandoning after having worked them for years, for the sake of the saving in operating. The *operation* of these railroads and not the interest on the cost of construction, is the great drain on their resources, which alone they are now able to check.

We must keep in mind that passengers who travel by rail will not permit any modification of plans by which their comforts are curtailed. They must have the same accommodations on the new lines that other companies have been giving them in the past.

But the point is, to do this more cheaply than it has been done. We begin to see that we have been laying breadth of road at extravagant cost for the sake, apparently, of throwing away its length. Thus, on our own line we must build 80 miles of road; in this matter of length we have no selection. Our duty, then, is to use up as much of this element, which will otherwise be wasted, as is possible, and save in the width, where we are permitted a choice, and are thus able to economize.

On this principle the Welsh railroad, connecting the Slate Quarries of Festiniog with Port Madoc, 13 miles distant, is built and operated.

That road has a gauge of about 23½ in., and cost an original capital of $180,000. From its earnings the Company has re-constructed the line in the most complete manner, erected workshops and manufactured rolling stock, until the expenditures have amounted to $430,000 in 5 years, all which has been capitalized. Notwithstanding this they declare an annual dividend of 12½ per cent. on the entire outlay, and their net profits have, from the beginning, been more than 40 per cent. of the original capital.

The success attending lines of small gauge railroads has been so uniform, that last year the officers and contractors of the Poti and Tiflis Railroad, 220 miles long in the Caucasus, recommended its adoption to the Russian Government. The recommendation carried the more weight, that the construction of the line was far advanced, and 10 miles of track laid on the standard Russian gauge of 5 ft. The Russian Minister of Public Works, Count Bobrinskoy, sent for the English Engineer, Mr. Fairlie, who went to St. Petersburg to explain the new system in detail.

The result was the appointment of an Imperial Commission, of the best engineers of the Empire, who visited England especially and gave the greater part of their attention to the Festiniog road, which I have mentioned.

The Indian Government, at the same time, appointed a Commission of English engineers to accompany the Russian Commissioners in their investigation, while, the spirit of inquiry seeming completely aroused, the London Board of Trade sent Capt. Tyler, Royal Inspector of Railroads, and the Norwegian Government sent Mr. Pihl, Chief Engineer of

Railroads in Norway. The Duke of Sutherland made one of the party, being not only a Director in the North-Western, but himself proprietor of a considerable length of railroad in his Sutherlandshire estates.

The result of the investigation has been entire unanimity of opinion among the members, "that the common railroad gauge of 4 ft. 8½ in. is far beyond all ordinary requirements." There was some difference of opinion as to what gauge is the best, the expression varying from 2½ to 3 ft.

Mr. Spooner, the Engineer of the Festiniog Railroad, the man who first built such a work and carried it to success, thinks a 2½ ft. gauge ample for the transaction of all ordinary railroad business.

And Capt. Tyler, the Royal Inspector of Railroads, has issued authority to the Festiniog Railroad Company to run passenger trains at any rate of speed they may desire, although when they first opened their road he limited their speed to 12 miles the hour. He declares in his report that he "travelled over this little road at 30 miles the hour with every feeling of safety."

The general conclusions, summed up by Capt. Tyler, are, that "a system of lines like this could be built, costing ⅔ of those now constructed and maintained at ¾ the expense, and would be of decided benefit to Great Britain and Ireland, and most valuable in India and the Colonies."

The 3 ft. 6 in. gauge is the standard in Norway, thanks to the good sense of her Engineer, Mr. Pihl, and Sweden has finally resolved to construct on the same gauge.

Two 3½ ft. lines are being built in Russia as a preliminary experiment.

The Brœlthal Railroad in Prussia, of 31 in. guage, is a financial success.

In France there are two private roads and one public work, the Mondalazac, of 29 in.

In Ohio a 2½ ft. railroad, 44 miles long, between Piqua and Celina, is about to be built for general traffic, through a rich and populous agricultural district like our own. This road connects with and crosses three other roads of the ordinary gauge.

A system of small gauge railroads is projected from Toledo, as feeders to the broad gauge railroads centring there.

It is now determined to build the line from Denver City to Santa Fe, more than 300 miles, on the small gauge system.

That it is the approaching system of the railroad world, intelligent men seem agreed.

An important paper read lately by Mr. Fairlie before the British Association, says "It ought to be engraved on the mind of every engineer, that every inch added to the width of a gauge beyond what is absolutely necessary for the traffic, *adds to the cost of construction, increases the proportion of dead weight, increases the cost of working,* and in consequence *reduces the useful effect of the railway.*"

In further support of what I have advanced concerning the economy of working the small gauge system, I ask your attention to some facts concerning the rolling stock of railroads.

It is customary to build cars for local passenger traffic, weighing 14 tons and possessing accommodations for 48 passengers. If such a car were filled there would be due to the weight of the car alone a load of 700 lbs. dead weight, for every passenger. But so far are these great cars from being filled in their daily runs, that a year's return from this State shows the average load on the New York Central to be only 17 passengers per car, with a load of dead weight, due to the weight of the car, of 1,840 lbs. per passenger. Referring to the figures given in a former part of this paper, we may compare the broad gauge of the Erie with the gauge of the Central, and learn that this drag of carrying a non-paying load is well illustrated in their experience. Thus the Erie road moves 3⅓ tons of dead weight per passenger, while the Central is encumbered with but 1½. If the doctrine of proportionate reduction hold good in this matter of gauge, then a 3 ft. road should permit equally comfortable cars, with a dead weight of but ¼ of a ton per passenger. And an actual calculation of the weight of such a car shows this to be the fact, *i.e.*, a load of dead weight of less than 500 lbs. per passenger.

III.—With this elucidation of the principle of small gauge roads, we are prepared, I think, to pass to the third and last point of this paper, namely: The application of these principles to our own purposes.

I have prepared an estimate of the cost of building a 36 in. road, and equipping it

with rolling stock, and a line of telegraph. It gives us for $1,000,000 what will cost $1,600,000 if built by the common system of 4 ft. 8½ in. gauge; a road 83 miles long, built and completed, including land damages, with all its sidings, depots and appurtenances, with a line of telegraph, and all the rolling stock necessary for 6 months' work.

I invite you to consider the full magnitude of this saving. For the $600,000 you are liable to a shrinkage on bonds of at least 10 per cent. The saving, therefore, represents a capital of $660,000, on which for 20 years, you are to pay 7 per cent. interest, or a total.....$942,000
And at the end of that time the capital..... 660,000

Thus in 20 years you will be drained of..... $1,620,000
Or 8 per cent. per annum on your capital stock of $1,000,000.

Suppose this amount saved; if, at the end of twenty years, your small gauge road is insufficient for your business, you have saved (out of your earnings if you can pay such interest) enough to build and equip a road of the common gauge, and do it without incurring debt.

* * * * *

The common car as now built, weighing 32,000 lbs. empty, hammers the rail with 4,000 lbs. on a wheel. The little car of the 36-in. gauge, weighs but 1,300 lbs. per wheel.

Similar advantages are obtained in the locomotive, which is built expressly for this system. An engine that bears 20 tons on its driving wheels, distributes 5 tons to each wheel, and with its loaded tender and its own uneffective load, weighs altogether about 50 tons, of which one-half is dead weight. In the Fairlie engine the entire load, including coal and water, is placed on the driving wheels, and thus utilized in the work of hauling the train. Instead of carrying 50 tons to procure the useful effects of 20, we have an engine weighing the 20 tons and no more; and this load is distributed over 8 driving wheels, giving but 2½ tons per wheel instead of 5, as in the ordinary engine of equal power.

So complete has been the success of the swivel-truck engine on these roads, that the Festiniog Railroad Company has already placed the 7th on their line. The reduction of weight per wheel, which they have introduced, allows us to use a rail of half the usual weight.

There were apprehensions in the minds of the managers of the Prussian railroad, that the little engines of their small gauge would be powerless in deep snow; but the result has shown them to be as effective in this as in every other position in which they have been used. The capacity of our road will be the equivalent of 1,000 tons per hour with the class of engine I have designated in the estimates; that is, 25,000 tons per day of 24 hrs., or 8,760,000 tons per year. This would be the same as 6,000,000 tons of freight and 4,000,000 passengers.

Last year the New York Central carried about this number of passengers and a half of this amount of freight. And the Erie, with 440 locomotives of the broad gauge capacity, did not reach these figures in either branch of their traffic.

I am aware that the grand objection in our case will proceed from the difficulty of making connections with other roads. But this difficulty is not so great as it seems.

On the small gauge road we can carry freight at so low a rate as to monopolize all traffic going in our direction. We present such inducements to rival connections, that we stimulate the effort to accommodate. One or other of these lines will understand that the only way of securing our work is to lay down the third light rail between their tracks.

If we build on the common gauge we are in no better position; we simply place ourselves at the mercy of one great corporation, while we cut ourselves off from other lines. On the small gauge, with a light rail, it costs but half the sum to connect with another line, and we have the choice between the two or more roads that we touch.

The law which leads any railroad to seek a port or important town, will draw them to our southern terminus with the means of taking away what we have brought. That terminus must be an important source of supply to be sought.

But we ought not to be anxious to put ourselves into the hands of any company, simply because it will accommodate our traffic with a third rail. By a simple mechanical device—an arrangement of track—we can easily and rapidly transfer

our loaded freight cars from the trucks of one gauge to those of another, and thus remain independent of the caprices of all connecting companies.

This system is pursued at Chenango Forks, where the cars of the 6 ft. gauge are sent over the narrow gauge of the Chenango Valley Road.

Let us keep in mind, that the ability to transport freight and passengers a distance of 80 miles at a cheaper rate than any competing company, makes us a power that will produce its own accommodation, so that we shall not be called on to sue for favors.

The transfer of general miscellaneous freight, such as coal, ore, grain, lumber, apples, vegetables, flour, cider and liquor in barrels, will cost—if we are able to keep our force of laborers at work constantly, with proper facilities—about 2 cents per ton.

Now, it is a matter of dollars and cents with us, not one of time, whether this is to be an unremunerative tax.

Two roads east and west of us, running parallel with our line, carried last year 100,000 passengers, and 200,000 tons of freight. Suppose we accept this as an estimate of what we may expect to do annually for a few years. The transshipment of this amount of freight will cost us $4,000. But to offset this charge, we are able to save ¼ cent. per ton per mile on our freight, and ½ cent per passenger per mile, or $80,000 on our year's work; and to this saving is to be added the $80,000 of reduced interest and capital shown in this paper to be due to the construction of a small gauge road. Here, then, is an annual expenditure of $4,000 to be offset by an annual saving of $160,000.

Is it worth while to hesitate longer on account of the difficulty of making connections?

One class of men opposes the construction of small gauge railroads; those who are interested as contractors, machinery and car builders and their dependents, among whom are railroad supply dealers, and the papers that advertise for them.

But railroad engineers, and the most intelligent capitalists who are interested in railroads, are very well agreed in this matter.

An important circumstance, as indicating what seems to be considered inevitable in this direction, is to be found in the issue of special advertisements by the locomotive and car builders, who, in spite of their prejudices and all their past interests, are preparing themselves to supply the new demand.

IRON AND STEEL NOTES.

The North Chicago Rolling Company are about to put in operation one pair of 5-ton vessels for the Bessemer process. The plant is to be established under the supervision of Mr. A. L. Holley, who acts as consulting engineer.

Works of the same magnitude, and under the same direction, will probably soon be built at Joliet.

Effects of Cold upon Iron.—The apparent undecisiveness of the experiments for ascertaining the effects of cold upon iron recently brought before the Manchester Literary and Philosophical Society, induced Mr. P. Spence to undertake a further series. He limited himself to ascertaining whether the reduction of temperature has any, and if so what, effect on cast-iron with regard to its powers of resisting transverse strain either of weight or pressure. As experiments made with iron of special quality are quite worthless for all practical purposes, Mr. Spence was careful to obtain such as might be considered as generally obtainable in the market. Messrs. Rye, Son & Ogden, of Newton Heath, carefully made 50 cast-iron bars, 3 ft. long by half an inch square, all out of one ladle, and of No. 3 Glengarnock pig, and Kirkless Hall common pig. Mr. Spence cut each bar into three lengths of 1 ft., the 150 pieces being thrown together in a heap; the ends were then covered with paint, that the new fracture might be examined; and the heap was then taken into his laboratory, so that it had three chances of perfect mixing. A boy 11 years old now handed him the pieces singly from the heap, and he placed them alternately one by one in two lots, until he had got 70 pieces in each lot. One lot was placed in a freezing mixture, standing at zero, for nearly 48 hours, and the other lot was put into water at 70 deg. Fahr., chiefly that the pieces might be broken wet, as those would necessarily be when taken out of the freezing mixture. The distance between the supports was exactly 9 in. in every case; and Mr. Spence's experiments prove that "cast-iron, having at 70 deg. Fahr. a given power of resistance to transverse strain, will, on its temperature being reduced to zero, have that power *increased* by 3 per cent." At the temperature of 70 deg. Fahr., the maximum breaking weight was 4 cwt. 3 qrs. 26 lbs., and the minimum 2 cwt. 2 qrs. 14 lbs., equal to an average of 3 cwt. 3 qrs. 6 lbs. At zero, the maximum breaking weight was 4 cwt. 3 qrs. 13 lbs., and the minimum 2 cwt. 3 qrs. 10 lbs., equal to an average of 3 cwt. 3 qrs. 11 lbs. The difference, therefore, is but 5 lbs., or less than 12 per cent., increase by the reduction of temperature. Adding together, however, the breaking weights of the 70 samples tested at 70 deg. Fahr., the total is 263 cwt. 3 qrs. 18 lbs., equal to an average of 3 cwt. 3 qrs. 10¼ lbs. The total breaking weight of the

70 samples tested at zero was was 276 cwt. 3 qrs., equal to an average of 3 cwt. 3 qrs. 22¾ lbs. The difference thus shown is 12½ lbs., or about 3 per cent. increase, as Mr. Spence states.—*Mining Journal.*

SUMMARY of abstract of experiments on the tensile strength of steel, made at H.M. royal gun factory, Woolwich; showing the average strength of each kind of steel tested, and the increase obtained by tempering:

Name of Contractors.	Nature of Materials.	Number of Specimens.	AVERAGE BREAKING WEIGHT in TONS per SQ. INCH.					
			When tested as received from Contractor or taken from Gun.	After being tempered in Oil at				Tempered in Water.
				High heat.	Medium heat.	Low heat.	Tempre. not stated.	
Krupp & Co	Cast Steel	9	32.095	65.385	54.385	56.440	....	....
Firth & Sons	Steel	3	34.436	....	....	....	....	....
Firth & Sons	Homogeneous Steel	217	31.640	47.720	47.96	47.04	44.43	....
Cammell & Co	Steel	2	26.595	....	....	....	....	....
Cammell & Co	Homogeneous Steel	61	29.48	54.575	45.66	51.505	48.966	51.100
None given	Steel	4	31.720	....	....	....	36.610	....
None given	Homogeneous Steel	36	28.967	....	37.18	....	39.33	53.93
Styrian Steel		8	56.150	....	82.15	....	....	....
Moser & Co	Steel	7	33.466	54.60	55.80	....	....	....
Whitworth & Co	Steel	2	38.200	....	48.20	....	....	....
		349						

POWDERED COAL FOR IRON SMELTING.—A surprising effect is produced in the operation of burning powdered coal, in several English furnaces owned by a gentleman named Crompton. The method was devised for the purpose of economizing fuel, and to save from loss the immense quantity of small coal wasted; and it consists in blowing the powdered coal into the furnace, and exactly the quantity of air requisite to effect complete combustion. A mass of flame of the highest temperature thus fills the furnace, and does its work without producing any smoke whatever.

BERARD'S PROCESS OF MANUFACTURING STEEL DIRECT FROM PIG IRON.—The enormous and increasing demand for steel has naturally directed attention to the cheapest method of manufacturing metal, which seems destined, for certain purposes, to supersede both cast and wrought iron. The Bessemer process is well known, having been for some years before the public. But a rival now appears in the field in the system of M. Berard, adopted at the steel works at Givors, Rhone, France, and now introduced to the notice of manufacturers in this country by Messrs. Whitney Partners, Hunsletroad, Leeds, who publish translations of M. Berard's pamphlets, and are his sole representatives in England. The principal points which M. Berard keeps in view in his process are as follows :

1. The employment of gas acting at once as a calorific and reacting agent in purifying the iron by a partial purification before throwing off prejudicial bodies (such as sulphur, phosphorus, arsenic, etc.)

2. The being able to employ iron of a secondary quality, to obtain steels for certain special purposes, such as rails, tyres, etc.

3. By the combined action of air and gas being able to act alternately by means of oxidization and reduction in keeping the waste at a minimum ; and by decarbonization and recarbonization regulate at will and with certainty the nature of the product to be obtained.

4. Organizing a plant which shall permit of working under the most economical circumstances.

In carrying out these principles the first point has been to secure a good gazogene. This has been effected by making an incandescent bed of coke at a high temperature traverse the gases. The decomposition of the tar and steam is rendered complete, and there is no trace of carbonic acid, while to increase the production of pure gas, particularly hydrogen, a jet of superheated steam is introduced, which aids at the same time to carry off the gases. The iron is run in a liquid state into the movable bed of the converting furnace. Two descending tuyeres, one on each side of the furnace, and having a divergent direction, are introduced into the metallic liquid, so as to cause each portion of the metal to come under the action of the current, which provokes a violent ebullition and produces a natural mechanical puddling. A simple arrangement allows the proportion of air and gas to be varied during the operation. When air is in greater proportion, the reaction is of course oxidizing, and it is reducing if the gas is increased beyond a certain point. During oxidization the temperature is considerably raised by the combustion of the carbon contained in the iron, the silicum, manganese, and a small quantity of the iron. The sulphur and phosphorus are transformed into sulphuric and phosphoric acids, which may be partly volatilized or may enter into the scoriæ. During reduction, the oxide of iron alone is reduced. The silica

combines with the oxide of manganese and the other bases in order to form silicates, which constitute the scoriæ of the bath.

The operation takes from an hour to an hour an a half, and the results of frequently renewed tests towards its close determine the point of decarbonization of the metal, and the instant at which this should be arrested in order to obtain the quality of steel desired.—*Mechanics' Magazine*

Product of the Lake Superior Iron Mines in 1870.

Names of Mining Companies, and Mines Worked on Lease.	Gross Tons of Ore Shipped by: Marq. and Ont. R. R.	Peninsula Division Chi & N. W. R. R.	Other Shipments.	Totals.
Jackson Mine	5,086	113,104	4,520	122,710
Cleveland Iron Mining Co	50,129	82,755	.....	132,884
Lake Superior Iron Co.	166,582	.....	....	166,582
Barnum Mine Iron Cliff Co.	.....	44,793	.....	44,793
Foster Mine, Iron Cliff Co	.....	23,458	.....	23,458
Washington Iron Co.	79,762	.....	.....	79,762
Pittsburg and Lake Angeline Iron Co.	21,232	53,467	.....	77,699
Champion Iron Co.	72,518	.....	643	73,161
New York Iron Co.	.....	90,702	4,107	94,809
New England Iron Co.	24,871	.....	.....	24,871
Marquette Iron Co.	3,702	.....	.....	3,702
Grand Central Iron Co.	.....	1,809	.....	1,809
McCumber Mine	3,002	1,864	.....	4,866
Parsons' mine	1,896	.....	.....	1,896
Winthrop Iron Co	3,469	.....	.....	3,469
Grand Total	435,249	411,952	9,270	856,471
Product of 1869				643,238
Increase				213,223

Pig Iron Produced for the Year 1870.

	Gross tons.
Morgan Furnace	5,952
Champion Furnace	5,576
Michigan Furnace	4,858
Greenwood Furnace	3,992
Bancroft Iron Co	3,710
Collins Iron Co	4,100
Pioneer Furnaces	5,853
Deer Lake Iron Co	2,500
Schoolcraft County:	
Schoolcraft Iron Co	2,809
Bay Furnace Co	3,498
Delta County:	
Fayette Furnace (estimated)	5,000
Total pig iron product	47,848
Product of 1869	38,504
Increase	9,344

Shipped as follows:

By Marquette & Ontonaga R. R	27,399
By Pennsylvania Division C. & N. W. R. R.	8,515
Other shipments	10,250
On hand at the furnaces	1,684
	47,848

Total shipments over the M. & O. R. R.:

	Gross tons.
Iron ore	435,249
Pig iron	27,399
	462,648

Total shipments over the Peninsula Division C. & N. W. R R.:

Iron ore	411,952
Pig iron	8,515
	420,467

Total Amount of Ore and Pig Iron Produced.

	Iron Ore, Tons.
1856	7,003
1857	21,000
1858	31,035
1859	65,679
1860	116,998
1861	45,430
1862	115,721
1863	185,259
1864	235,123
1865	195,256
1866	296,872
1867	460,320
1868	498,290
1869	643,238
1870	856,471
Total	3,768,695

	Pig Iron, Tons.
1858	1,629
1859	7,258
1860	5,660
1861	7,970
1862	8,590
1863	9,813
1864	13,832
1865	12,283
1866	18,437
1867	30,911
1868	36,425
1869	38,504
1870	47,848
Total	293,160

Total Amount and Value of Iron Produced.

	Tons, Iron Ore.	Tons, Pig Iron.	Value.
1856	7,003	....	$28,000
1857	21,000	....	60,000
1858	31,035	1,629	249,202
1859	65,679	7,258	575,529
1860	116,998	5,660	736,496
1861	45,430	7,970	419,401
1862	115,721	8,590	984,977
1863	185,259	9,813	1,416,935
1864	235,123	13,832	1,867,215
1865	195,256	12,283	1,590,430
1866	296,872	18,437	2,405,960
1867	460,320	30,911	3,475,720
1868	493,290	36,425	3,676,705
1869	643,238	38,504	4,973,435
1870	856,471	47,848	5,339,804
Total	3,768,695	239,160	$27,799,809

ST. LOUIS AS A STEEL MANUFACTURING CENTRE.—The St. Louis "Republican" urges the fact upon the attention of its readers that that city might in a few years become the Sheffield of America, if enough capital and enterprise are applied to the development of its superior facilities for the manufacture of steel ware. The "Republican" shows that in the Shepherd Mountain district, within a few miles of the city, there are exhaustless quantities of the best ore for the manufacture of steel of the choicest and most serviceable qualities. Mr. Otto Worth, a practical iron analyst of Pittsburg, has lately made an analysis of the pig iron of the South St. Louis Iron Company, and finds that the metal contains the following component elements in the proportions given below:

Silicon	2.98
Carbon (1.68 combined, the rest graphite)	4.21
Sulphur	.002
Phosphorus	.067
Iron	91.97
Slag	.77
	99.999

In his report upon the analysis, Mr. Worth says: "It is an excellent iron, very well adapted to the Bessemer process, as it contains carbon and silicon enough to work very hot, and is free enough from sulphur and phosphorus to make neutral steel—neither cold nor red short. It is also the best material to be used in the so-called Siemens-Martin process." On the strength of this and other scientific endorsements, the "Republican" urges that an immense and almost immediately lucrative field of industry is open to the capitalists of St. Louis; a field in which the already great demand is certain to experience a swift and permanent growth. The "Republican" announces that rolling mills for the manufacture of steel rails will soon be in operation in the city; and several of the railroad companies propose undertaking the manufacture of their own rails. A prospectus for cast-steel works at St. Louis has also been prepared, which estimates the required capital at $1,500,000, and the production at 30,000 steel rails per year, with a profit of $1,200,000. At $100 per ton, the present price, the resulting value would be $3,000,000. Supposing this estimate to even approximate accuracy, the promise seems great enough to encourage the liberal investment of capital.

OIL FUEL FOR IRON SMELTING.—A day or two ago a trial was made at the Illinois Central Railroad shops, of the value of Whipple & Dickenson's petroleum fuel, in a smelting furnace. It was a most satisfactory and pronounced success; a white or melting heat being reached in just 53 min. from the time of starting the fire. To attain this result it has always taken, before this, 4 to 4½ hrs., and the consumption of a large amount of coal. The Illinois Central Company and its employees are highly pleased with obtaining a better heat in so little time and so cheaply.

DEMAND FOR STEEL RAILS.—"Herapath's Railway Journal" (London) says: "We hear that every steel rail manufactory in the country is now in full orders for the next 2 years, and that the price of the best Bessemer steel is some £12 per ton. The difficulty now appears to be not to pay for steel rails, but to get them. This great demand for them arises from the marked economy in their use. Considerable savings are being made by our railway companies in the maintenance charges, due to steel rails. Thus experience has already supported theory as to the great advantage of steel rails."

RAILWAY NOTES.

DELAWARE AND HUDSON CANAL RESERVOIR.—It is reported that the company have purchased a large tract of land in Sullivan county, about 7 miles from Wurtsboro', upon which is Lord's Pond, a large inland lake. Upon this land they have commenced the construction of an immense reservoir, which will be fed by waters from the pond, and, in time of need, will add its supply to the canal, and prevent even such a drouth as that of last year from affecting transportation. The reservoir will cover 209 acres. The dam will be 923 ft. in length, and 23 ft. in height, giving a "head" of 20 ft. It will require, above the base line, 7,000 cubic yds. of earth for the sloping embankment above the dam, and 3,000 yds. of dry masonry and 320 yds. of cement masonry for the bulkhead. The work will cost, it is estimated, about $15,000.—*Railroad Gazette.*

BALTIMORE AND OHIO RAILROAD SHOPS.—At the Mount Clare shops of the company they are busy building ten-wheeled freight engines, of what will seem to railroad men of a higher latitude somewhat peculiar construction. They are ten-wheeled engines, with 6 driving-wheels 50 in. in diameter, and have cast-iron tires, which are used exclusively on this road. The distance from the centre of the back driving-wheels to the centre of the truck is only 15 ft. 4½ in. This makes it necessary to place all the driving-wheels ahead of the fire-box.

The cylinders are 19 in. diameter and 22 in. stroke, and are inclined at an angle of about 1 in 6. The valve gear is the old double-expansive valve, worked by eccentrics and hook motion. The cab is on top of the boiler, and the fire-box is inclined downward from the top of the barrel of the boiler. The crown-shut is stayed with stay-bolts, the same as the sides of the fire-box. The grate is 59¼ in. long × 42¼ wide. The boiler has 134 2¼ in. tubes, 14 ft. long. The shell is 48 in. in diameter, made of ⅝ in. iron, and double riveted all through. The fire-box is made of steel, with the exception of the tube-shut, which is made of copper.

These engines weigh 73,000 lbs. in working order. We could not learn the relative weights on the drivers and on the truck.

Although these locomotives may appear somewhat antiquated, yet, after long experience with freight engines of different kinds on this road, it was thought that those of the plan described gave better results than any others. It must be remembered, too, that they are obliged to work on curves of 400 ft. radius, for which they are especially adapted by the shortness of their wheel-base.

The first engines of this plan were designed by Mr. Samuel J. Hayes, now Superintendent of Ma-

chinery on the Illinois Central Railroad, in 1853 or 1854.

The Baltimore and Ohio Railroad Company has built 10 of them for the Pittsburg and Connellsville Railroad, which has just been opened.

About 1,500 hands are now employed at the Mount Clare shops.

INDIAN RAILWAYS.—A survey party has commenced operations on the proposed Indian state lines from Indore to Ajmere. The line will pass *via* Ullmuch, but the route generally has not yet been settled. The surveying party comprises Mr. Miller, superintendent; Lieutenant Firebrace, R. E., Lieutenant Dundas, R. E. (from the public works secretariat, Calcutta), Captain Downing, from the topographical survey, Lieutenant Begbie, R. E., etc. M. Le Messurier, the agent of the Great Indian Peninsula Railway, Mr. Conder, the general manager, and Mr. Middleton, the district traffic manager, have been inspecting the works in progress between Goolburgh and Raichore. Everything is stated to be going on well.

IT is not yet 2 years since the great Union Pacific line of railway was opened throughout its 3,361 miles of length, from New York to San Francisco, and already American enterprise is sighing for fresh fields to conquer. It is not enough that two other great lines connecting the east and west coasts should have been projected—one at the extreme north and the other at the extreme south of the United States,—nor that the most northern of these should have been already commenced. Such triumphs would be but tame repetitions of that already won. Nothing less will suffice than the solution of a problem which has been the despair of all the generations since Cortes. The American isthmus must be cut, and sea joined to sea. The thing has been done indeed, so far as travellers were concerned, years ago. The railway across the isthmus of Panama was projected immediately upon the discovery of the Californian gold fields, and opened to traffic so far back as 1855. For commercial purposes, however, this line has proved almost worthless, both on account of the expenses and danger of transshipment, and the badness of the harbor on the Atlantic side. Experience has now also shown that the great Pacific Railway is quite inadequate to supply the needs of a through commerce between the Atlantic and Pacific oceans. This project of cutting a canal across the American isthmus is, as we have said, anything but a new one. Above a dozen routes have been projected, and three or four have been actually surveyed. Of these, apparently by much the most feasible is that through the river San Juan and the great lake of Nicaragua. The dividing neck of land between Nicaragua and the Pacific is actually only about 15 miles in breadth. But to cross this a deep cutting of 2 miles, a tunnel of 1 mile, and descent of 200 ft. by locks would be necessary. The grand object of search has always been a route which, like the Suez Canal, should be practicable without any locks at all. At last it is believed that this has been discovered. Two expeditions are engaged in the work of exploration; and one of these, under Commander Selfridge, professes to have been most successful. A New York correspondent states that the new route is projected to run from the Gulf of Darien on the Atlantic to the Gulf of San Miguel on the Pacific, and has deep and capacious harbors at both ends. The total length from sea to sea would be about 120 miles, but the length of the canal itself, connecting the rivers Atrato and Tuvra, would be less than half that distance. The highest level to be crossed would be about 170 ft. above the sea level, and 200 above the highest river level; but the rock at this point is friable, and might easily be cut. The estimated cost is about £5,000,000, and the time necessary to complete the work about 5 years; but, of course, these estimates must be conjectural. Still, it really seems as if there were a fair chance that a second cutting, of even greater importance to the commerce of the world than that at Suez, would speedily be made. The voyage from New York to Kohohama would be shortened by 8,000 miles. From Liverpool the Suez route would still be 1,500 miles shorter than the Darien, but the Darien would be a good deal the safer. The Americans are getting considerably excited about the matter, as they well may; and San Domingo acquires a new importance in their eyes as a great trading station of the future.—*Mining Journal.*

ENGINEERING STRUCTURES.

THE PROPOSED INTERNATIONAL BRIDGE AT BUFFALO.—The construction of the new bridge across the Niagara river at Buffalo, will establish another and important connection between Canada and the United States. The value and importance of an international bridge at this point has long been acknowledged by those interested in the railway system of the two countries, and the work of building it would long since have been undertaken if unity of action could have been obtained among the different railway interests which are to be benefited by it. It is now to be undertaken by the Directors of the Grand Trunk Railroad of Canada, and although a private enterprise as far as its ownership is concerned, it will be of great value to the railroad systems of both countries. It will be, in fact, a short connecting link through which will pass the direct and indirect traffic from at least a score of American and Canadian railways.

The locality selected offers unusual facilities for the construction of such a bridge, and the completed work promises to yield a handsome profit upon the capital invested. A small island, lying about midway between the American and Canadian shores, affords facilities for sinking the foundation and building the central piers, and in this respect it will differ very greatly from the suspension bridges which span the rapids below the falls of Niagara. The new bridge will have a carriage and footway for passengers and ordinary vehicles, as well as its double track railways for trains. Its entire cost will not exceed $1,250,000. It is undertaken under an Act of the Dominion Government, and also an Act of the United States, which declares it to be a postal road, and to be available for the use of all railway companies, upon payment of the same rates and tolls as are charged upon other parts of the Grand Trunk line. The Directors of the Company are clearly within the mark when they estimate the increase in their traffic at half a million dollars a year, and it is not improbable that the net profit upon the increase of business will alone equal the amount. We have not yet received any detailed statement

of the plan upon which the new bridge is to be built, but it is said that no trouble or expense will be spared to make the structure in all respects the strongest and best of its kind on this side of the Atlantic. The work will be intrusted to competent hands, and will be pushed to completion without unnecessary delay. The construction of central piers of substantial masonry will render the bridge better adapted to railway purposes than one crossing the river with a single span, and when it is possible to build such piers without impeding navigation, we think the long span may be advantageously dispensed with.—*Iron Age.*

PLATT RIVER BRIDGE.—Mr. J. B. Moulton, Chief Engineer and General Superintendent of the Omaha and Southwestern Railroad, is engaged in making surveys for the bridge over Platt river about 7 miles from the junction with the Missouri river. The Nebraska Legislature has offered 20,000 acres of land to aid the undertaking. One location that has been made, but not yet finally decided upon, requires one span of 150 ft. over the first channel; 3 spans, in all 500 ft., across a towhead of Cedar Island; 400 ft. over the main channel; 1,000 ft. of trestle work on the island, and 800 ft. of trestle work on the south bank—in all 2,850 ft. In crossing the main channels, the engineers have partially located the bed-rock at a distance of 60 or 70 ft. below the bed of the river. With the exception of one strata of coarse gravel and loam, with perhaps another of bituminous shale, this deposit upon the bed-rock is a fine sand.—*Railroad Gazette.*

FROM the report of the proceedings of the Institute of Civil Engineers we extract the following description of a wrought-iron pier at Clevedon, Somerset, by Mr. John William Grover, M. Inst. C. E.

In this communication the author stated that the Act for constructing a pier at Clevedon was obtained in the session 1863–4, but little was done upon the ground till the spring of 1868, which was singularly boisterous and unpropitious. The works were virtually completed at the end of the same year, and had since stood well, without material damage.

The coast of Somersetshire at this spot was composed of dark cliffs of magnesian and mountain limestone, of which large fragments were scattered about the beach, the spaces between them being filled with soft mud. The site selected for the work was tolerably free from these obstructions, being a thin promontory of rock, level from right to left, and dipping seawards at an angle of 12 deg. to 8 deg. Beyond this came mud 13 ft. deep, upon boulders and clay. At the head, a ridge of sand 2 ft. deep covered a bed of hard red clay, giving a tolerable bottom. The chief difficulty was, however, the great rise and fall of the tide, viz., 45 ft. at springs. As the Bristol Channel was only nine miles across at this point, the water acquired the velocity of a mill-race on the ebb, or 5½ miles an hour. Clevedon was also exposed to high seas from the south-west.

The structure comprised, first an approach of masonry, 20 ft. wide and 180 ft. long, with a falling gradient of 1 in 10; secondly, the body of the pier was formed of 8 spans of 100 ft. each, supported upon piers of Barlow rail piles, spreading to a wide base at the foot and clustered at the top. From below the girders arched ribs of Barlow rails were connected to the vertical piles. The main girders of the structure were continuous, 3 ft. 6 in. deep, and 800 ft. long, the flanges being 1 ft. 6 in. wide, and all of wrought iron. The Barlow rails of the piles weighed 80 lbs. per yard each; they were riveted back to back, and were filled with a preparation of coal tar. The main girders were placed 16 ft. 6 in. apart; the seats, which were continuous, rested upon the top flanges, and the pier at the parapets was nearly 19 ft. wide. The floor was laid with close planking 3 in. thick, which ran longitudinally, and presented, with the camber of 3 in. in the middle, an appearance like a ship's deck. The sides or parapets were close boarded. Below low-water mark the Barlow rails were discontinued, and the piles consisted of solid stems of wrought iron 5 in. in diameter, screwed to depths varying from 7 ft. to 17 ft., with cast-iron screws 2 ft. in diameter.

The pier head was 50 ft. long by 40 ft. wide. From the ground line to the deck it was 68 ft. high. There were 5 lower stages or landing-decks, 10 ft. apart, connected by wide staircases. The head was composed of piles of Barlow rails weighing 70 lbs per yard each, riveted back to back; they were connected together with rolled joists, and were strongly braced by diagonal ties. The length of the longest pile was 76 ft., and the pier was accessible at low water of spring tides. One span was tested with a central load of 42 tons, when the deflection was 1¼ in. in the centre.

The weight of wrought iron employed was less than 370 tons, and of cast iron 7 tons. The cost of the work was under £10,000.—*The Engineer.*

THE steamships Africa and Great Northern, loaded with the section of submarine cable to be laid between Shanghai and Possiette Bay, on the Russian-Chinese frontiers, for the Great Northern Telegraph, China and Japan Extension Company, are probably on their way out. They were to leave before May 1st.

NEW BOOKS.

REPORT ON CERTAIN EXPERIMENTAL AND THEORETICAL INVESTIGATIONS RELATIVE TO THE QUALITY, FORM, AND COMBINATION OF MATERIALS FOR DEFENSIVE ARMOR. Made by direction of Brevet Major-General A. A. HUMPHREYS by Brevet Major W. R. KING, Captain of Engineers. Washington: Government Printing Office. For sale by Van Nostrand.

A voluminous and well printed work, and is without doubt an exhaustive treatise upon the important subject of defensive armor. It is illustrated by 28 lithographic plates.

IRON AND HEAT. By J. ARMOUR, C.E., 1 vol. 18mo. London: Lockwood and Co., 1871. For sale by Van Nostrand.

In "Iron and Heat," Mr. Armour has collected in the compass of 164 pages, the fundamental principles and facts concerned in the construction of iron beams, pillars, and bridge girders, and the action of heat in the smelting furnace. The mechanical portion is illustrated by 55 diagrams, some of which are quite new and highly ingenious. The work is designed to benefit those who are more intimately acquainted with practical operations as workmen than with the principles

on which that practice is based; common arithmetic only is used, and the author successfully carries out his "endeavor rather to explain circumstantially the rules of common use than to develop new theories." The sections on iron smelting are rudimentary, but the action of heat in its various operations inside the furnace upon the different materials concerned is so closely followed that the essential conditions of the smelting process may be easily understood. The volume is a suitable and useful addition to Weale's celebrated series.

FRAGMENTS OF SCIENCE FOR UNSCIENTIFIC PEOPLE. By JOHN TYNDALL, LL.D., F. R. S. London: Longmans, Green & Co. 1871. For sale by Van Nostrand.

This new work of Professor Tyndall's is a series of detached essays, lectures, and reviews, not quite new except in the form of a collected volume. It contains the papers on Dust and Disease, and various others, such as an essay on the Constitution of Nature, from the "Fortnightly Review;" Thoughts on Prayer and Natural Law, an extract from Mountaineering in 1861; on Miracles, and Special Providences, a review from the "Fortnightly;" on Matter and Force, a lecture at Dundee in 1867; an address on the Scope and Limit of Scientific Materialism in 1868; one on the Scientific Use of the Imagination, delivered before the British Association at Liverpool; a "Rede" lecture on Radiation; a discourse on Radiant Heat; one on Chemical Rays and the Light of the Sky; one on Faraday; a lecture on Magnetism; and others, including some shorter articles on Slates, Miracles, Science, and Spirits, etc.

Mr. Tyndall's writings, while full of scientific interest, are often rhetorical and poetical; and the delusive "Spirits" of whom he speaks do not seem to have been far wrong, in one thing at least —namely, in styling him "the poet of science," which they declared to be already his name in "the other world."

THE SEVEN PERIODS OF ENGLISH ARCHITECTURE DEFINED AND ILLUSTRATED. By EDMUND SHARPE, M. A., Architect. Second Edition. London: Spon. Birmingham: Birbeck. 1871. For sale by Van Nostrand.

The second edition, recently published, of Mr. Sharpe's "Seven Periods" is enlarged chiefly by eight additional plates of Lincoln choir, nave, and presbytery, and Peterborough choir. In these days of masterly scratches and meagre lithographs it is refreshing to see a set of well-finished, clear, and precise line engravings, reminding older readers of the days of Le Keux. Mr. Sharpe's divisions and titles have been set forth and reviewed on several occasions in these pages, so that we need not just now again discuss them. Readers, without being bound to substitute the terms *Curvilinear* for "Decorated,' and *Rectilinear* for "Perpendicular," will find the characteristics of the various periods of English architecture succinctly and clearly set forth, and will be sure to derive advantage from a study of the book. The illustrations make a capital set of copies for architectural students.

GEOLOGICAL SURVEY OF OHIO. Part 1. Report of Progress in 1869. By J. S. NEWBERRY, LL. D., Chief Geologist. Part 2. Report of Progress in the Second District. By E. B. ANDREWS, Assistant Geologist. Part 3. Report on Geology of Montgomery County. By EDWARD ORTON, Assistant Geologist. Columbus: Nevins & Myers. For sale by Van Nostrand.

This affords a new addition to the stock of geological information of our country. A very neat map is folded in the volume, giving by colors the extent of each of the groups of rocks. A chart in another place exhibits the parallelism between the Ohio and New York series, and shows also the relation of each to the European rocks.

The triple report occupies 176 pages.

THE JOURNAL OF THE IRON AND STEEL INSTITUTE. This journal, of which the first number has recently appeared, promises to be of exceeding interest to all who are directly or remotely concerned in the metallurgy of iron and steel.

Number one contains 276 pages, and several engraved plates.

The contents in this and future numbers is comprised under the following classification:

1st. Proceedings of the Institute and of the Council, with reports of the meetings.

2d. Original papers and communications relating to the manufacture of iron and steel.

3d. A short general report of the statistics and progress of the manufacture and trade in Great Britain, since the appearance of the previous number.

4th. A similar report as to what has been done elsewhere throughout the world, with references to the original sources of such information.

A large portion of the present number is occupied by Mr. J. Lowthian Bell's paper on the chemistry of the blast furnace.

The next number may be expected within a period not exceeding three months.

PRELIMINARY EXPERIMENTS ON THE MECHANICAL AND OTHER PROPERTIES OF STEEL, MADE OR COLLECTED BY A COMMITTEE OF CIVIL ENGINEERS. London. For sale by Van Nostrand.

These tabulated results of careful experiments are exceedingly valuable.

The specimens tried are of well-known brands, and the tests to which they are subjected are such as to make known the peculiar virtues of each manufacture.

A summary of these tests is given in another place in our present issue.

The experiments were directed by Mr. Kirkaldy.

MISCELLANEOUS.

AMERICAN EMERY.—The existence in the United States in reliable quantity of so rare and useful a mineral as emery, and its successful introduction into use, are two interesting facts; and the latter marks an important stage in our progress in manufacturing. The Ames Manufacturing Company, of Chicopee, Mass., has been long celebrated for the excellence of its swords, bayonets, bronze cannon, etc; and many not familiar with these articles will remember the famous bronze doors in the Capitol at Washington, as well as the various Colossal Bronzes from their works which adorn Union square, N. Y., and other public squares and grounds throughout the country. It is an auspicious circumstance that a man of the practical skill and the high reputation of the President of

the Ames Manufacturing Company should be responsibly connected with the manufacture of this emery. There can certainly be no reasonable doubt of the genuineness of the mineral or of the faithfulness of its preparation.

We have devoted some thought and inquiry to this subject, deeming it of interest to a large portion of our readers. Until so recently as 1868, the emery trade of the United States seems to have been wholly in the hands of those who manufacture and sell the emery mined in Turkey. Many of the foremen and grinders being foreigners, and none of them knowing even of any but imported emery, the line of foreign occupation seemed not only complete. but formidable. If "possession gives nine points," the tenth was surely in the same hands, by reason of the intense prejudice against any "new emery," and most of all against any such article of American mining.

To aid in thus holding the market by the imported article, the duty on the Turkish ore has since been removed, and since 1869 the list price of the emery ground from it has been twice lowered.

Still the American mined emery has vigorously and rapidly made its way; and many of the largest consumers and most critical judges of emery not only would decline the best foreign emeries at the same price, but use the American to the exclusion of all others. This we find to be specially the case with the cutters of the precious stones, and manufacturers of lenses for optical instruments, spectacles, etc. The grinders of the hardened steel also speak in equally strong terms of this emery. If it meets the wants of such consumers as these, we do not see how it can fail of satisfying all who grind softer materials. The recent extensive introduction of "solid emery wheels" has widened the range of use for emery, and a maker of these wheels tells us that in turning them off with a diamond tool to prepare them for use, he finds the Chester emery to resist and cut his tool more vigorously than the best of the imported emeries.

Such facts as these certainly seem to be the best possible auguries of success, and the eminent firms engaged in selling the Ames' Chester emery throughout the country are the last men who would sell an inferior or even a second rate article. This is much to accomplish in so short a time.

The appearance of one or two imitations may perhaps be taken as an evidence of its excellence. A worthless article would be hardly worth imitating The quiet but still successful introduction of the genuine Chester emery could only have been effected by an article of intrinsic merit ; and we think our readers will agree with us that it constitutes a real and interesting advance in American manufacturing interests.—*Iron Age.*

New Road Material.—It has often been remarked that of all streets London streets are the dirtiest in wet weather, the dustiest in dry; and for 9 months out of the 12 not only positively dangerous to travel upon, but damage our horses, carriages, and even our temper to an alarming extent. Who has not seen frequently horses thrown down, and almost cut to pieces, from the looseness of the material of which our roads are made ?

It is well known that hitherto the principal material used in road making and repairing is the broken granite from the quarries of Guernsey or those of Leicestershire, and the very nature of it is quite sufficient to account for our discomfort. For building purposes, perhaps, granite is the most lasting, under a condition of rest; but when placed on roads, and subjected to the crushing and grinding operation of wagon-wheels, it quickly becomes reduced to powder, and, having no cementing properties, is in dry weather blown into our houses, or converted into mud in wet, bespattering our persons, if we are unlucky enough to be obliged to walk. It is not our present intention to remark upon the asphalt which has been laid down in one or two of our principal thoroughfares, as its first cost will deter most of our vestries from adopting it, and time alone can show its value. But in meantime attention may be called to the fact that we possess, to an almost boundless extent, a material in every degree superior to granite. This is the Ironstone slag, and for the benefit of our readers not connected with the iron trade, we may slightly digress to explain what this is.

In the production of pig-iron from the raw material there is a large amount of dross, which flows from the surface of the molten metal in the furnace, and is received in what are called "slag boxes;" these when filled are drawn away and emptied to waste, and this material when cold assumes a pale French gray color, and is what we now designate "Ironstone slag." From an analysis nowbefore us there can be no doubt of its cementing properties—its greatest value ; and the fact that in Belgium and France it has been moulded into an almost endless variety of forms, both for building and road-making, should be sufficient to convince us of its utility. For the formation of a road it should be broken into paving blocks, about 6 in. cube, and packed loosely together, covered with the same broken to a 2 in. gauge about 4 in. deep, or 10 in. together ; afterwards to be well watered, and rolled together to crush the whole, thus forming a road which for cleanliness and comfort cannot be surpassed. For simply repairing an existing road it is sufficient if laid on 2 in. thick.—*Mining Journal.*

The Suez Canal.—The Suez Canal has now been a twelvemonth working, and it is officially stated that the receipts average about £20,000 a month, or about £240,000 a year. The headquarters of the Company being in Paris, the war and siege have prevented the usual official report being made, which should have given information regarding the net as well as the gross revenue ; but the statement as to the gross traffic affords some material for a retrospective glance at the anticipations of traffic and profit which were indulged in a twelvemonth since, and which we showed to be exaggerated. The promoters of the enterprise, it will be remembered, did not shrink from calculating on a traffic of 2,000,000 or 3,000,000 tons of shipping per annum, and this immediately ; and no doubt if the canal had such a traffic, it would pay very well. The canal would do very well, we said, if at first 1,000,000 or 2,000,000 tons of shipping annually made use of it. The statistics now published show that the average traffic has not yet reached the figure of 1,000,000 tons—receipts of £240,000 per annun at ten francs per ton only implying a trade of about 600,000 tons per annum. In point of fact, now that we have experience to guide us, the canal has had unexpected luck in obtaining even this traffic. The screw steamers which use it almost exclusively are of a kind which did not exist a very few years ago ; and it is cer-

tain the promoters could not have foreseen that when the canal was inaugurated, not only would such steamers be in existence, but a number of them laid up, or about to be laid up, for a want of business, would be suddenly available for a new venture. But for the remarkable progress of mechanical invention since the canal was commenced it must have been a stupendous failure ; and but for the singular conditions of the shipping trade at the time of its inauguration, its start, though far short of the promoters' anticipations, could not have been so good as it is. The practical question now is how the canal is to be kept open ; and the gross return will, perhaps, be sufficiently good for this purpose, though we do not know yet what the working expenses have been. It will be ludicrously insufficient even to pay the debenture holders, whose annual claim is double the amount of the gross receipts ; but if there is only a surplus of any sort to be dealt with, there will be some possibility of a new organization of the Company, or the purchase of its undertaking by the Egyptian Government.—*Economist.*

JARRAH JARRAH TIMBER.—One of the most important products of Western Australia, as regards constructive materials, is the jarrah jarrah wood or mahogany of those parts. The advantages of this timber are its great strength, hardness and closeness of grain, combined with durability under exposure either to salt or fresh water. It is never attacked by white ants nor by the *teredo navalis*, which abound in tropical and semi-tropical seas, and this confers upon it an additional value. It somewhat resembles red gum in appearance, but the grain is darker, finer, and closer than that of the latter wood, and it is susceptible of a very high polish, which brings out a rich dark hue. It is invaluable to the Western Australians, who use it for ship-building, pier, and railway construction, as well as for the interiors of buildings and for furniture. In proof of its usefulness and durability in subaqueous operations, we may mention that three piles were drawn last year after having been in use for 30 years at the Perth Causeway Bridge over the Swan river, Western Australia. The piles, when drawn, appeared to be as sound as the day on which they were driven in, although they were half under water the whole of the time. A piece was sawn off the whole length of each of the three piles, one surface being polished and the other left rough, so that the soundness of the timber is apparent. The facts connected with these piles are vouched for by Mr. J. Manning, clerk of the works at Freemantle, Western Australia. In contrast to this may be mentioned the circumstance attending the use of three heavy sheer-legs of Baltic timber during the construction of the same bridge. The portions of these legs which were under water were completely riddled in the course of ten months by the *teredo navalis*, while the three jarrah piles do not show the slightest signs of insect ravages after 30 years' immersion in the same water. The immunity of this wood from the attacks of insects, whether land or marine, has been proved by analysis to be due to the presence of tannic acid in the wood.

Although this valuable wood has hitherto been but little known beyond the colonies, it will doubtless shortly come into more general use, as a company has been formed for supplying the market on a large scale. It was organized about two years since, under the title of the Western Australia Timber Company, and the Government ceded to it 320 sq. miles of jarrah jarrah, tooart, and karie timber country, with 2,000 additional acres of land for every mile of railway made by the company. The area selected by the company is about 12 miles from Geographic Bay, which lies to the north of Cape Leuwin. The works consist of a loading jetty, which was completed towards the close of last year in that Bay ; a line of railway 12 miles in length from the Bay to the timber district, and mills for sawing the timber. The railway and the mills were very nearly completed when the last mails left Australia. The company anticipated being in full working order very soon, and they expect to be able to supply jarrah timber at the same price as charged for red gum—a greatly inferior timber. The company have works at Ballarat, where they have accumulated a large store of jarrah and tooart wood. This tooart wood is a species of white gum, and has a very close grain, is extremely hard, cannot be split, and is capable of enduring great heat without rending. The tooart wood has been suggested for use in gun carriages, on account of its non-liability to split. Jarrah jarrah timber is being used by Government in the construction of military barracks in Ceylon, where it is supplied at little more than half the price charged for Indian teak. Possessing such advantages as the jarrah timber does, there can be little doubt of its commanding an extensive market, and proving useful in a variety of ways, as well as remunerative to the enterprising individuals who have embarked their capital in it.

IMPROVED METHOD OF PRODUCING HYDROGEN GAS.—MM. Tessie du Motay and Marechal, who have lately discovered a mode of obtaining cheap oxygen for illuminating and medical purposes from the manganates of soda, have sought a more practical and economical method of producing hydrogen by the decomposition of water by means of carbon, and they have discovered the following method, which has given the most extraordinary results. Alkaline and earthy alkaline hydrates, such as the hydrate of potash, soda, strontium, baryta, chalk, etc., mixed with charcoal, coke, anthracite, pit coal, peat, etc., and heated to a red heat, are decomposed into carbonic acid and hydrogen, without further loss of heat than that due to the production of the carbonic acid and hydrogen. The hydrates of potash, soda, etc., and more especially the hydrates of chalk or lime, decomposed by the coal into hydrogen and carbonic acid, can be used indefinitely in this process, provided they are moistened each time with water, so as to reproduce the decomposed hydrates. In this operation, the hydrogen gas is generated without any special production of steam, and may thus be produced without any other generating apparatus than the retorts themselves. These retorts, not being exposed to the direct action of the steam, are not subject to any interior alteration or damage. It follows, therefore, that the hydrogen gas produced by the decomposition of the above-named hydrates by means of carbon can be generated at a very small cost, and with the same facility as carburetted hydrogens from the distillation of pit-coal or other organic hydro-carbon matter. These alkaline and earthy alkaline hydrates may be mixed with the

different mineral or vegetable combustibles, either in a definite chemical proportion, or without a fixed or determinate proportion, and in any suitable distilling or heating apparatus, in order to produce, when heated to a red heat, hydrogen gas for illuminating and heating purposes. The advantage of the production of hydrogen as cheaply as oxygen, which has been obtained, is likely to create a revolution in many industries, and especially in metallurgy. A cheap method of producing a great heat in order to reduce metals, such as platinum, gold, silver, and iron, has long been sought for in Europe, where the oxyhydric blowpipe is now used to melt the platinum in a calcium crucible. By this discovery it becomes possible to obtain an immense heat which could be regulated by a simple tap. Enamellers and porcelain makers may thus get rid of one of their greatest troubles.—*Journal of the Society of Arts.*

On the Melting of Lead Projectiles by Impact.—In "Poggendorff's Annalen," Mr. E. Hagenbach applies the mechanical theory of heat to account for some of the results of the experiments recently made at Basle, with the view of using targets of iron instead of wood in practice with fire-arms. Strong plates of iron were fired at from the distance of 100 paces. Conical bullets, by their impact against the iron plate, produced scarcely perceptible indentation, and fell down near the target; at the same time the lead projectile was melted to a very considerable extent. This could be recognized by the fact that around the point where the ball had struck, the plate was spattered with lead in the form of a white star; that, moreover, the melted lead was found in the vicinity, and that of the original bullet, which weighed 40 grammes, only the comparatively small portion of 13 grammes remained. By the author's calculation, the force expended on the ball gives, as mechanical equivalent of the heat, 0.49 thermal unit. He then proceeds to inquire how much heat is necessary to produce the melting described. The entire projectile (40 grammes) had to be raised to the temperature of the melting-point of lead, or near it; and the 27 grammes had to be melted. Assuming 100 deg. C. as the initial temperature of the ball, which was somewhat warmed by the heat of combustion and by friction, the melting point of lead being 335 deg. C., its specific heat 0.031, and its latent heat of fusion 5.37, he finds necessary for heating 0.29 thermal unit, and for fusion 0.15, giving a total of 0.44 thermal unit, this being only .05 less than the estimated mechanical equivalent. Thus the mechanical theory of heat sufficiently accounts for the operation. Almost all the impetus of the motion of the body is transformed into heat—a result which was indeed to be expected, seeing that the iron plate was very slightly deformed, and the projectile rebounded but little. By far the greater portion of the heat was used in heating and melting the lead. This is also readily understood; for the short time within which the entire process was effected could give rise to but littles loss by conduction and radiation.—*Engineering and Mining Journal.*

A Mississippi River Item.—The engineer officers who have charge of the surveys and improvements upon the Western rivers report that the Mississippi river is changing its channel, so that Vicksburg will soon become an inland town unless immediate preventive measures are taken. The main channel is now immediately under the bluffs upon which the town stands, making one of the best harbors upon the river, but in a few months the engineers are confident that a cut-off will be formed across a low sandy peninsula opposite Vicksburg, through which the greater portion of the current will pass, leaving not enough water at the levees of the town to float steamboats. To prevent this, it will be necessary to construct an expensive stone revetment, which it is estimated will cost $2,745,535.

The Geology and Mineral Resources of Siam.—Comparatively little has been published with reference to the geology of Siam; but a correspondent kindly furnishes a series of valuable notes as to the best sources available on the subject. Much information will be found in "Mohat, On Siam and Gambodia," probably to be found in the library of the British Museum, although it is not in the library of the Geological Society of London, nor in that of the Royal School of Mines. In Mr. J. Crawford's "Descriptive Directory of Indian Islands" (p. 379), there are some very interesting notes on Siam. They refer to a district from 4 deg. to 22 deg. of north latitude, and 1,080 geographical miles in length, embracing an area of about 111,000 geographical miles. Three mountain chains, taking a north and south direction, are referred to as running between the equator and 14 deg. north latitude; and iron, tin, and gold have been found in the continuation of the middle chain and in the most westerly part through the Malay Peninsula. The formation is sedimentary and plutonic. Between 13 deg. and 14 deg. on the western borders of Siam, lead, zinc, and antimony have been found, but never worked; but gold, which is found associated with tin, has received more attention. The noted mines of Bangtapan are between 10 deg. and 12 deg. and "Three Hundred Peaks," and have yielded some fine rubies and sapphires. Prof. Royle (*re* Banca) likewise contributed some valuable information to the Geological Society of London, in communications "On the Mines of Tenassarim Province,' which were published in their "Proceedings" between November, 1843, and April, 1845. In the "Quarterly Journal" of the same society (vol. 13, p. 188), Messrs. Moyle and Hillier give a "Notice of the Occurrence of Metalliferous Ores and of Coal in Siam," in hills extending north and south from latitude 15 deg. 25 min., near the river Chaw Phya (Meinam). In this notice was announced the discovery of apparently valuable copper veins, principally of grauwacke, also of lead and silver, and enormous beds of magnetic and specular iron. In the country to the north, carboniferous limestone, with indications of coal, has been met with, and on the eastern coast of Siam beds of coal have likewise been discovered.—*Mining Journal.*

Curious Property of Gun-Cotton.—Dr. L. Bleekrode, in a paper published in the "Philosophical Magazine," gives some account of experiments in which he tried to ignite gun-cotton with the electric spark. He thought to facilitate its explosion by wetting it with a highly inflammable liquid, as, for example, the bisulphide of carbon. But it was only this latter substance that was immediately set on fire by the spark—while the gun-cotton did not explode, but remained apparently intact amidst the burning bisulphide, presenting almost

the aspect of a mass of snow slowly melting away; the same effect is produced by moistening gun-cotton with bisulphide of carbon, ether, benzine, or alcohol, and igniting it afterwards with some flame or other; all these liquids yield the same results and are without danger, even if great quantities are used; the explanation of this, Dr. Bleekrode finds in the researches of Professor Abel, "On the Combustion of Gun-cotton and Gunpowder." These results indicate that it, even for the briefest space of time, the gases resulting from the first action of heat on gun-cotton upon its ignition in open air are impeded, from completely enveloping the burning extremity of the gun-cotton twist, their ignition is prevented; and as it is the comparatively high temperature produced by their combustion which effects the rapid and more complete combustion of the gun-cotton, the momentary extinction of the gases, and the continuous abstraction of heat by them as they escape from the point of combustion, render it impossible for the gun-cotton to continue to burn otherwise than in the slow and imperfect manner, undergoing a transformation similar in character to destructive distillation.

Centrifugal Pumps.—A paper on centrifugal pumps was read lately before the Institution of Civil Engineers, by Mr. David Thomson, who stated that the first really successful centrifugal pump was that contributed by Appold to the Exhibition of 1851, in which the vanes were bent backward, which mode of construction is still followed in the best pumps. Mr. Thomson says that the depth of the revolving fan or radiating arms should be $\frac{1}{4}$ of the diameter, and that the central opening for the admission of the water should be about $\frac{9}{16}$ of the diameter over the blades. The fan revolves in a case which should be of much larger diameter than the fan itself. The best duty of the pump is given when the speed of the periphery of the fan exceeds the velocity of a body falling through the height of the lift by from 6 to 8 ft. per second. A fan 12 in. in diameter, and proportioned as described, will discharge 1,200 gallons of water per minute, and the delivery, the speed of the periphery of the fan remaining the same, will increase as the square of the diameter. In small pumps the duty is about 55 per cent., and in large about 70 per cent. of the indicator power of the engine from which the motion is derived.

Galvanized Iron.—A method of estimating the quantity of zinc existing in the plating of galvanized iron, has been communicated to the "Philosophical Magazine," by Mr. T. Warren. The principle of this method consists in the use of mercury to dissolve the zinc, when the loss of weight can be easily ascertained. But a thin coating of an amalgam of iron and zinc will remain, which will take up a certain quantity of mercury, and the amount of this amalgam present is measurable by the quantity of mercury it will take up. To determine this quantity of mercury, the iron is weighed, then heated to drive the mercury off, and then weighed again, when the weight of mercury which has mixed with the amalgam will be at once ascertained.

Durability of Cast-Iron Water-Mains.—I took up some 8-in. cast-iron pipe last year, which had been in use since 1828. It was made in Philadelphia, and laid in the mill-yard of the Merrimac Manufacturing Company, in connection with the force-pump, for fire purposes. Until 1849, the head on them did not much exceed 150 ft.; since then it has been about 200 ft., exclusive of the effect of water-hammer.

The interesting point, however, is its state of preservation. Thinking it might be of interest in connection with the proposed discussion, I send a section of the pipe. When taken up it was lined with tubercles, projecting say $\frac{1}{4}$ to $\frac{1}{2}$ of an inch. As the pipes were intended to be relaid, and in fact have been, except 2 or 3 pieces, they were scraped out. The outside remains pretty much as when taken up, except as the rust has jarred off in carting the pipe. Thirty-nine years' use appears to have made but little impression upon it.—*Extract from a Letter from James B. Francis, Civil Engineer, 27th July, 1868, to A. W. Craven, Member of the Am. Soc. of Civil Engineers.*

The Mercurial Battery of Marie Davy.—This galvanic battery, which has lately been extensively and almost exclusively used in France, is not so universally known as it deserves. It is composed of zinc and carbon; but in place of diluted acid the zinc is simply immersed in pure water, while the carbon is immersed in a paste of moistened sulphate of mercury. The chemical action is similar to the Daniell battery, consisting of zinc, copper, and sulphate of copper. The zinc is oxidized at the expense of the water, which is decomposed, its oxygen combining with the zinc, forming oxide of zinc, while the hydrogen in its nascent state reduces the oxide of mercury, combining with the oxygen, forming water, and leaving the mercury in a metallic state. In this condition mercury cannot remain in combination with sulphuric acid. Hence, the latter is also set free and combines with the oxide of zinc, forming sulphate of zinc, exactly as is the case in the Lowe, Daniell, and other batteries, while the metallic mercury collects at the bottom of the vessel. Such a battery may remain in operation for half a year without cleaning or the addition of liquid. The current generated by 40 small elements has the same power as that from 60 of Daniell's larger ones, which lasted less than half the time.—*The Telegrapher.*

The following illustration, says Professor Henry, of the vibratory movement of matter is attested by Professor Horsford, of the United States. The top of the high tower which constitutes the Bunker Hill monument inclines towards the west in the morning and the north at mid-day, and towards the east in the afternoon. These movements are due to the expanding influence of the sun as it warms, in succession, the different sides of the structure. A similar but more marked effect is produced on the dome of the Capitol of Washington, as indicated by the apparent motion of the bob of a long plumb-line fastened to the under side of the roof of the rotunda and extending to the pavement beneath. This bob describes daily an ellipsoidal curve, of which the longer diameter is 4 in. or 5 in. in length. By molecular actions of this kind, Time, the slow but sure destroyer, levels with the ground the loftiest monuments of human pride.

The New York caisson for the East River Bridge was successfully launched on the 8th of May.

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